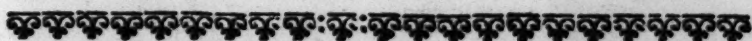




Micrographia Illustrata :
OR THE
MICROSCOPE
EXPLAINED.



Micrographia Illustrata :

OR THE

MICROSCOPE



EXPLAINED.

The Variable MICROSCOPE.
and Lamp By George Adams N^o 60.
Fleet Street London.

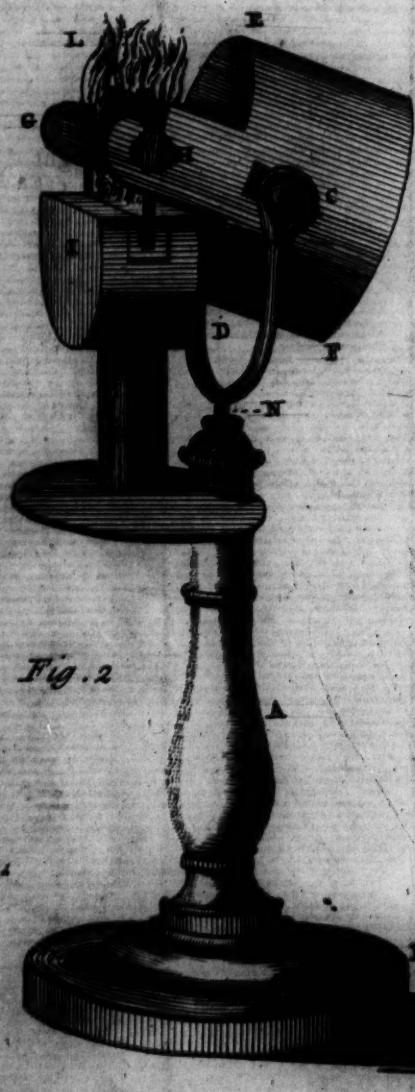


Fig. 2



Fig. 1

Goodnight sculp.

From the title page

44 c 15

Micrographia Illustrata :
OR THE
M I C R O S C O P E
EXPLAINED,

IN SEVERAL NEW INVENTIONS,
Particularly of a New VARIABLE MICROSCOPE
for Examining all Sorts of Minute Objects ;

AND ALSO OF A
New CAMERA OBSCURA MICROSCOPE,
Designed for Drawing all Minute Objects, either by the Light
of the Sun, or by a Lamp in Winter Evenings, to great
Perfection ;

WITH
A DESCRIPTION of all the other Microscopes now in Use.

LIKEWISE
A NATURAL HISTORY OF AERIAL, TER-
RESTRIAL, AND AQUATIC ANIMALS, &c.
Considered as Microscopic Objects.

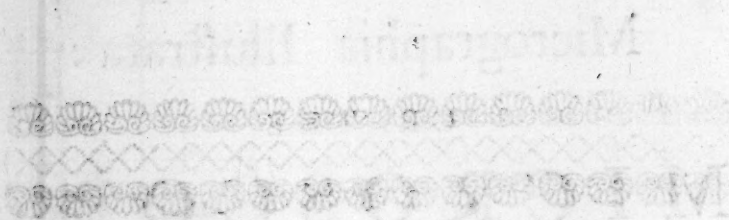
By **GEORGE ADAMS**,
Mathematical Instrument - Maker to His MAJESTY.

THE FOURTH EDITION.
Illustrated with Seventy-two Copper Plates, containing 560
Delineations of various Microscopic Objects.

L O N D O N :
Printed for the AUTHOR, and sold by him at No. 60, in
Fleet-Street, and by all Booksellers in Town and Country.

M.DCC,LXXI.

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PREFACE

THE study of nature, or in other words a serious contemplation of the works of God, is certainly one of the most pleasing and useful, as well as most extensive kinds of knowledge. It is the great and proper object of our rational faculties; for surely we cannot employ our reason better, than in endeavouring to make ourselves acquainted with the glorious works of that Being, to whose goodness we owe our own.

Natural Philosophy is now to greatly improve in all its several branches; that few persons who have had the happiness of a liberal education, are unacquainted with the science of it. It is so prevalent that we are apt to lose sight of the works of nature from outward appearances.





P R E F A C E.

THE study of nature, or, in other words, a serious contemplation of the works of God, is certainly one of the most pleasing and useful, as well as most extensive kinds of knowledge. It is indeed the great and proper object of our rational faculties; for surely we cannot employ our reason better, than in endeavouring to make ourselves acquainted with the glorious works of that Being, to whose goodness we owe our own.

Natural Philosophy is now so greatly improved in all its several branches, that few persons, who have had the happiness of a liberal education, are wholly unacquainted with the value of it. But prejudice is so prevalent, that we are apt to form an absolute judgment of the works of nature from outward appear-

P R E F A C E.

ances only; and so imagine, that the most grand and magnificent parts of the creation are most perfect, and for that reason most worthy of our regard. The splendor of the sun is visible to every eye, and we need only look upwards in order to be convinced, that nothing less than an infinite power and wisdom could first create the universe. What, but an Almighty hand, could raise such a glorious canopy as that of the heavens, so richly adorned with stars? Or stretch out such a spacious area, as this terraqueous globe on which we tread, and sail; and which is furnished with every thing that is necessary for our support or happiness? And indeed these great truths are so very obvious to the lowest capacities, that few persons pretend to dispute them; but then it must likewise be owned, that men are generally apt to confine their attention to the most shining parts of philosophy, and so treat every thing else with coolness and indifference, and even with some degree of contempt. But surely a true philosopher is one, who diligently pursues the study of nature, in all its several branches; who can behold with admiration her noblest productions, and yet view with pleasure the smallest of her works;

P R E F A C E.

works ; in short, one who thinks every thing excellent, that owes its formation to her skilful hand. Nor is this a forced and imaginary description, but a real character ; and we need only take a transient view of some of those creatures, with which all parts of the earth are so plentifully stored, in order to be convinced of the justness of it. For whether we regard their elegance, and beauty ; or consider their fitness to answer those purposes, for which they were designed ; in both these respects we shall find, that the smallest creatures are perfect in their kind, and carry about them as strong marks of infinite wisdom and power, as the greatest. How many curious animals inhabit the air, and what numbers traverse the deep waters ! The whole earth is full of life ; there not being a single tree, plant, or flower, but what affords food and shelter to a species of inhabitants peculiar to itself. And then if we call in the assistance of art, what a new scene of wonder opens to our view ? What an infinite variety of living creatures present themselves to our sight ? Indeed their extream minuteness may at first seem a just argument for that low opinion, which too many are apt to entertain of them ; however, if we examine

P R E F A C E.

them with closeness and attention, we shall soon discover their divine original. We shall then survey with admiration the wonderful art and mechanism of their structure, wherein such a number of vessels, fluids, and movements, are collected into a single point, and that often invisible to the naked eye. What a profusion of the richest ornaments, and gayest colours, are frequently bestowed upon one little insect! and yet there are millions of others, that are as beautiful and wonderful in their kind. Some are covered with shining coats of mail; others adorned with plumes of feathers; and all compleatly furnished with those weapons, that are most proper for defending themselves, as well as attacking their enemies. In short, the more we enquire into nature, the more excellent she appears, and we shall constantly find, that the beauty of her works will gradually rise in proportion to our knowledge of them. There is no such thing as meanness in any of her productions; some indeed may be more grand, and happen to strike our senses more strongly than others, but all are perfect in the highest degree.

If then a serious contemplation of the works of God, may justly be considered as an excellent

P R E F A C E.

lent kind of knowledge, and worthy of our pursuit; and if all those works, though different in degrees of splendor, are still perfect; it is hoped, that an humble attempt to improve, and encourage the study of any branch of Natural Philosophy, will not be unacceptable to the public. And since the knowledge of the microscope has always been looked upon as no inconsiderable branch of Natural Philosophy, and as that part of it has particularly fallen within the compass of my studies, I have made it the subject of the following treatise; a subject, which has so often employed the most learned men, that it can hardly stand in need of an apology for the choice of it.

In this edition is given a description of several new and valuable discoveries.

I. The new variable microscope, which is both single and compound.

II. A beneficial improvement of the solar microscope, in which we have succeeded beyond expectation. By this acquisition; we have now an opportunity of examining all microscopic objects, either in the sun-shine, or at night in winter evenings.

III. A

P R E F A C E.

III. A new application to the pyramidical camera obscura, by which means perfect drawings may be taken of all those beautiful microscopic objects we are enabled to collect, by tracing their out-lines either with a pen or pencil, and that by any person who is not accustomed to drawing.

IV. We have given a description of the camera obscura, and have shewn how to apply it in taking perspective views of any landscape, in three different forms of the same instrument, by which means faces may be out-lined to great exactness, and pieces of still-life drawn from nature.

V. We have likewise added a new compendious pocket microscope, which is both single and compound.

VI. We have also given a description of the best kind of modern microscopes now in use, that the reader may comprehend the utility of each, and thence be enabled to judge, which may suit his purpose best.

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Micrographia Illustrata :
OR THE
MICROSCOPE
EXPLAINED.

A description of the new variable microscope.

Y this microscope we are enabled to examine the structure, and discover the various and surprising contrivances, in the exact and uniform proportion of the minute parts of the creation ; either in animals, insects, fossils, or vegetables, &c.

We owe the construction of the variable microscope to the ingenuity and generosity of a noble person. The apparatus belonging to it is more convenient, more certain, and more extensive than that of any other at present extant ; consequently the advantage and pleasure attending the observations in viewing objects through it, must be as extensive in proportion. I shall not detain the reader with dwelling upon its merits, but leaving the instrument to speak for itself proceed to a description of its several parts.

b

ABC,

A B C, fig. 1 and 3, represent the body of the microscope which contains two eye glasses at A, a third near B, and a fourth in the conical part between B and C, the end C shews one of the magnifiers screwed thereto.

Hence the body of this microscope, consisting of five glasses, greatly exceeds the usual compound microscopes which have only three, by increasing the field of view and of light, as well as affording an occasional opportunity of increasing the magnifying power of each particular lens, or magnifier; this is performed by pulling up the part A E which separates at A; there is likewise another separation at B, by pulling up the outward tube A B.

Another advantage attending this instrument is, that any two of the magnifiers may be used at the same time, as follows, see fig. 3. screw the button b to the part c of the button a, and both together into the body at c, the magnifier represented at c being first removed.

There are seven of these buttons represented at a and b, with magnifiers in them, also six silver specula highly polished, each having a magnifier adapted to the focus of its concavity, one of these is represented at e; when used they are to be screwed into the body of the microscope at c, every one of the seven magnifiers in the buttons a, b, may be used with any one of these specula, by screwing the lower part of the frustrum of a cone, which is seen at d, upon the prominent screw on the silver speculum at e, and then screwing the part c of any button b into its upper end, and altogether into the body of the microscope at c.

Note, these magnifiers are numbered, 1, 2, 3, &c. and the least number is the greatest magnifier.

The body of the microscope A B C is supported by an arm F, into which it may be put or taken out occasionally, and fastened by the screw at f; this arm is fixed to the bar G G, which may be raised or depressed by turning

turning the large ivory head I; the screw at H being first discharged, G G slides close to the upper part of the long bar K L, which last is fixed at N and N, to the toothed wheel N O N, this wheel being strongly supported by four scroles whose extremities are connected to an horizontal plate n, which gives an horizontal motion to the wheel N O N, the bar K L, and every other part of the microscope which is connected thereto, the whole being supported upon the pillar M, by the three feet P P P.

In fig. 3. the variable microscope is delineated from its perpendicular position, being that which gave the best representation of its several parts. In fig. 1. it is drawn inclined, from a view of which there will be no difficulty to conceive that on turning the key S, the pinion which works in the teeth of the wheel N O N will give the bar K L, with the microscope and its appendages, any oblique inclination that may be required.

The object carrying piece or stage D D D, has a large round hole T, in the middle over which we place the objects for observation, sometimes in an ivory slider, No. 1. fig. 3. or upon a slip of glass, No. 2. or they may be put upon one of the round glasses No. 2. fig. 3. which are of various colours and fitted to the hole at T.

The concave mirror Q Q turns vertically on the extremities of the semicircle g, and horizontally in the cylinder h, by which means it may be turned into any direction, so as to reflect the light from a bright cloud through the center of the stage at T, projecting the image of the object thro' the body of the microscope to the eye at E.

The mirror Q Q, may be extremely well illuminated at night by means of a new apparatus contrived for that purpose; it is represented at fig. 2. and consists of a pillar A B, that supports a semicircle C D; on the extremities of this, a short tube E F, turns upon axes, one

of them is seen at C, a lamp IK is suspended from the two ears G and H in such a manner that at every inclination of the tube EF, the flame L may direct its light through the center of the tube, and also of a plano-convex lump contained therein, and thence through an oiled paper, or a grey glass, to the illuminating glass QQ. The light thus transmitted to the mirror is amazingly fine, it being nearly equal to that reflected from a bright white cloud on a fine summer's day.

The object carrying piece DD hath a conical pin fitted to a hole in the slider W, in which it may be turned sideways, so as to examine the several parts of any object that may be too large for the field of view.

The scrole hR, has also a conical pin fitted to a hole in the slider V.

By means of the slider W, the object carrying piece DD may be readily set nearly to its proper distance from the magnifier in the button at C, and then by turning the large ivory head I, the body of the microscope may be brought to its distinct focus. But if this should not be thought quite sufficient, tighten the screw at H, and thereby turning the screw at X, the focus may be adjusted to the eye of any observer with great precision, and by moving the slider V a little higher or lower, a proper spot of light of any convenient breadth may be readily obtained.

No. 3. is a cylindrical tube, in which an inner tube is forced upwards by a spring; its use is to receive an ivory or glass slider, No. 1 and 2, the object being first placed in the center of the hole at m, or the object may be laid upon a glass slider, No. 2. either of which are to be put between the plates h and i, and the cylindrical piece No. 3. put into the hole at T in the stage X to which it is fitted. The hollow at k is to receive the glass tube, No. 10. for confining a small water animal to shew the circulation

The Microscope explained.

v

circulation of the blood. No. 11. is a wier screw to assist in cleaning the tubes, or to discharge their contents.

If the animalcula in fluids, or any minute insect, are under consideration, it will sometimes be necessary to exclude some part of the light which is reflected from the mirror Q, by putting the cone No. 4. upon the bottom l of No. 3. it being first put into the stage at T.

The nippers No. 5. are for confining any object, and are to be placed in one of the small holes near the extremities of the stage, or in the socket r, at the end of the chain of balls No. 6. as the pointed nippers t, which hold an opake object t v, the stage D D being removed, and one of the silver specula screwed to the body of the microscope at C, the slider W brought nearer to the slider V, the stem X of the pillar belonging to the chain of balls, being put into the hole at W, the balls may be readily managed to give a proper direction to the object t v, the observer's back being turned towards the window, so that the reflection from the mirror Q, of the sky behind, or on one side, may fall upon the silver speculum, and thence be returned upon that part of the object t v, which is to be examined and is next the eye.

No. 7. is a box, containing spare talcs to supply the ivory sliders.

No. 8. is a double convex lens, to be used as a magnifier in the hand.

Lastly, remove the body A B C, and put the stage D D in its stead, at B in the arm F; also put the pin f of No. 9. into the hole at z in the top of the bar K L, fig 3. place an object upon the stage, and screw any one of the magnifiers before described into the end e of the sliding bar e g, and then this instrument becomes a single microscope to which all the above apparatus is applicable; but for the use of the single microscope only, there are added three more magnifiers whose foci is very short.

There are also added to this apparatus already described, two glass planes broader than that of No. 2. and two others with hollows ground in them; they are to be laid upon the stage DD, to receive any accidental object that may occasionally offer. Small live insects may be confined between two of them, one having a hollow, and the other being a plane surface. Those with hollows in them are proper to observe the animalcula in fluids, being laid upon the stage.

The circulation of the blood may also be very well observed in the tail of any small fish, as well as between the toes of a frog, by tying it to one of the long glass plates, marked No. 2. in fig. 3.

There are likewise a few flat round glasses, No. 12. of different colours, fitted to the hole T, in the stage DD, and a watch glass fitted to the same place, which will hold more water than the hollows in the long glasses just above mentioned, and a set of glass tubes, No. 10.

To these if desired may be added a micrometer, and a frog frame, which will be described in their proper places.

There are two sockets fixed to the slider W, one of which is seen at p, fig. 3. Their use is to hold the frog frame if required.

The use of the improved solar microscope.

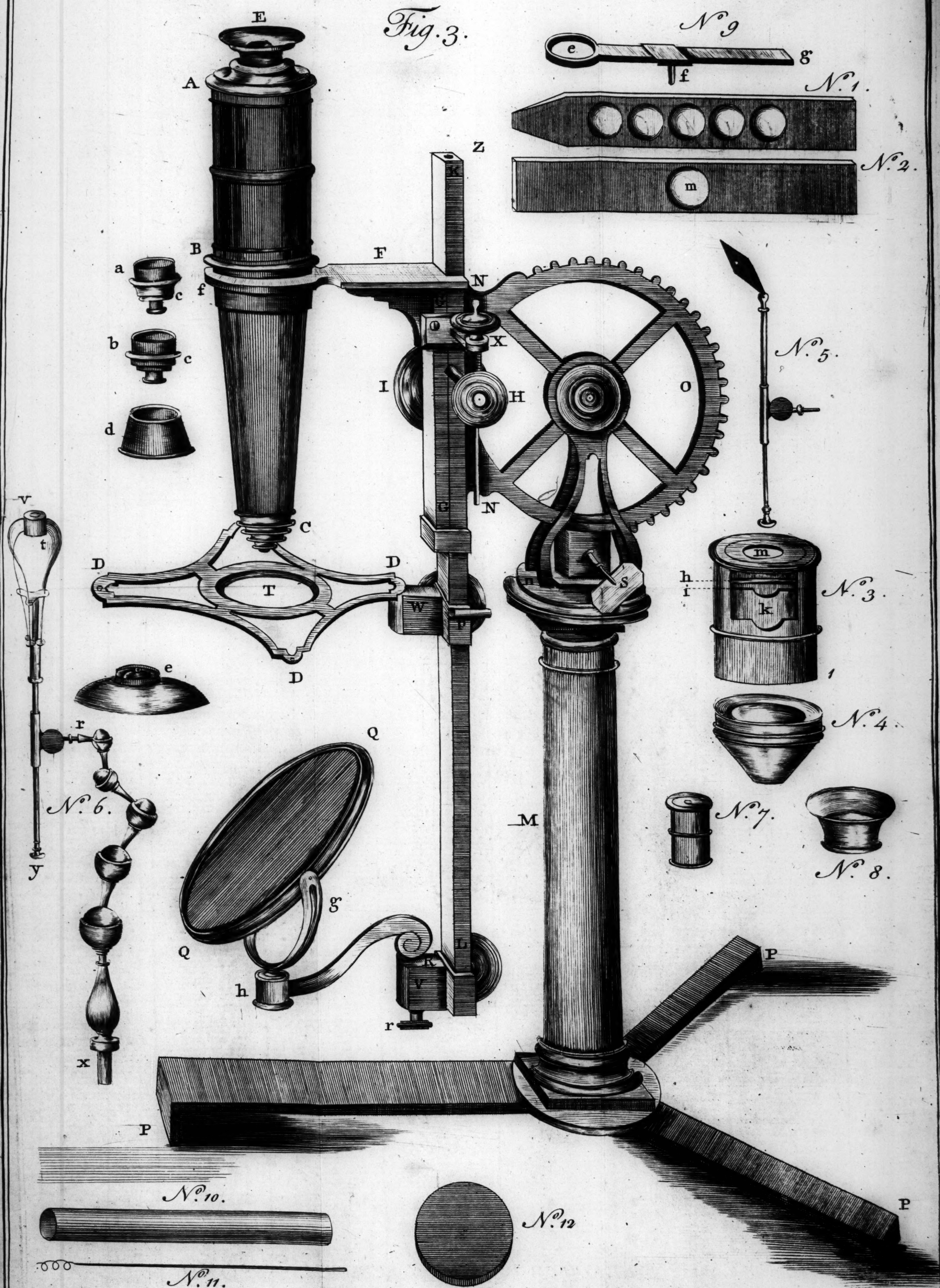
THIS microscope, from the very great extent of its magnifying power, and the convenience of viewing any object by many persons at one and the same time, gives more satisfaction and greater pleasure than any other microscope to the generality of observers; as will appear by the following directions, in shewing how it is to be applied.

Make

THE VARIABLE MICROSCOPE

By George Adams, N^o 60, Fleet-Street, LONDON.

Fig. 3.



Make a round hole in the window shutter, about 4 and 1-8th inches diameter; to which apply the square plate A A, fig. 4. with the circular part D uppermost, then mark the places of the two holes aa with a small black lead pencil, and bore them through the shutter of a size sufficient to let the mill'd headed screws B B pass freely through them, which entering the holes aa, will hold the plate fast to the inside of the window shutter; the looking-glass C, being first put through the hole, will remain on the outside of the window, the sash or casement being first thrown open.

Screw the part bb of the sliding tubes I K into the hole at H. Then prepare the microscope fig. 5. for observation. Take out the tube I, and screw the tube M into the end N of the microscope NP, and put the short slider R that contains a convex lens, to increase and enlarge the field of light, into the dove-tail plate g k h.

Place the object which is supposed to be either in an ivory or on a glass slider, as E or F, between the thin plates cd and gh, then screw on one of the magnifiers at the hole i. There are six belonging to this tooth and pinion microscope, and one of them is represented at Y. Or if the magnifiers are placed in a wheel as P Q * turn it so as to bring one of them under the center of the hole at i. Then darken the room as much as possible, that no light may enter, but what passes through the tubes I K. From this circumstance, and the brightness of the sun-shine, you are only to expect a perfectly clear and distinct image.

Now adjust the looking-glass C to the position of the sun, by turning the heads at e and f, the first inclines
the

* Note, we prefer the use of the magnifiers set in round buttons as represented at Y, instead of being set in a circular plate P P.

the mirror to the right or left, and the other raises or depresses it, so as to reflect an horizontal ray of the sun's light through the tubes I K, upon a screen of white paper placed about five or six feet from the window, which will form thereon a round spot of light.

Lastly, slip the tube I into that marked K, together with the microscope and object as before prepared; and if the sun then shines bright, you will have a distinct image of the object upon the screen, by turning the button at O to remove the magnifier to its proper focal distance.

There are six magnifiers in the wheel P Q, which turn round for the greater ease in changing from one magnifying power to another. When the room is darkened, all the magnifiers * are numbered, 1, 2, 3, &c. the least number being the greatest magnifier.

In the box with this microscope, there are also three short brass sliders, like that marked R, for increasing the field of light: on the first is engraved 1 and 2, to shew that this is only to be used with the first and second magnifiers. The second brass slider like R, being marked with the numbers 3 and 4, are to be used with the third and fourth magnifiers, and no other; and the third having the numbers 5 and 6, is only to be used with the fifth and sixth magnifiers. This is a principal improvement in the solar microscope, arising from the great increase of light we obtain thereby. The same advantage is gained when N P, which we call the tooth and pinion microscope, is used alone as a single microscope.

We have shewn above how to form a round spot of light upon the screen, but this cannot always be attained, because the sun's apparent altitude to the inhabitants of

* We prefer the magnifiers set in round cells as at Y, to those set in a wheel as P Q.

of northern latitudes in the winter, is so near the horizon, and more especially when the sun is directly perpendicular to the front of the room, it cannot then form a spot of light perfectly round; but if the sun be on either side of that perpendicular, a round spot may be obtained.

The most useful magnifiers in the solar microscope, are the fourth, fifth, and sixth.

Care must be taken to pull out, or thrust back, the tube I more or less, as the object is capable of sustaining the sun's heat, so that the spot of light may be broad enough to cover the object. Dead bodies may be placed within about an inch of the focus of the double convex lens, which distance must be shortened for living creatures, or they will soon be killed.

If the light falls not exactly right, you may easily direct it thro' the axis of the microscopic lens; and there keep it during the time of your examination, by the help of the screws f and e, by following the sun's motion.

Having taken notice of a screen to throw the images of objects upon, such a screen is usually made of a sheet of the largest elephant paper, strain'd on a frame, which slides up and down on a round mahogany pillar, in the manner of some fire screens. A larger sort are composed of several sheets of the same paper pasted together on cloth, and let down with a roller from the ceiling in the manner of a large map.

Fig. S. which is seen below the figures 4 and 5. represents that additional part of a solar microscope, which is designed for the examination of larger transparent objects, than can be contained in the apparatus already described, and is called a magellescope.

When this is to be used, unscrew the cap T V, from the inward sliding tube I, and screw the apparatus S in the place of it, the sliders for this purpose are made of mahogany as W, with three large round holes, each furnished

furnished with a pair of thin glasses; these are to be put between the plates *r f*, and *t v*, then by turning the button *w*, the convex lens or magnifier *z*, may be removed to a proper focus, so as to exhibit a distinct image of the object upon the screen. There are three such mahogany sliders, like *W*. and three others with larger holes represented at *X*.

A description of the tooth and pinion microscope, considered as a single microscope.

THIS instrument *N P*, fig. 5. with its apparatus of six magnifiers fixed in buttons like *Y*, which are to be screwed into the end *i P*, instead of the wheel *P Q*, makes a complete and useful single microscope, when put into a pocket case with ivory sliders *E*, glass slips *F*, small brass sliders *R*, glass tubes, &c. the use of each of these parts have been already shewn. To which may be added to the side of the microscope, an arm or handle, when designed to be used with the aquatic or Mr. Ellis's microscope, which will be described hereafter.

The use of the new improved solar microscope, applied to a new improvement on the pyramidal camera obscura, when illuminated by the solar rays.

SEE figure 6. in which *AB*, *AC*, represent two sides of the camera obscura when put together, its upper sliding tube represented at *P Q*, fig. 8. being taken out and laid aside, the circular box *ADF*, put on in its stead and held fast by two bolts, this being done, slide the arch *GH*, fig. 6. into its receptacle at *K*, and set the degree answering to the latitude of the place
you

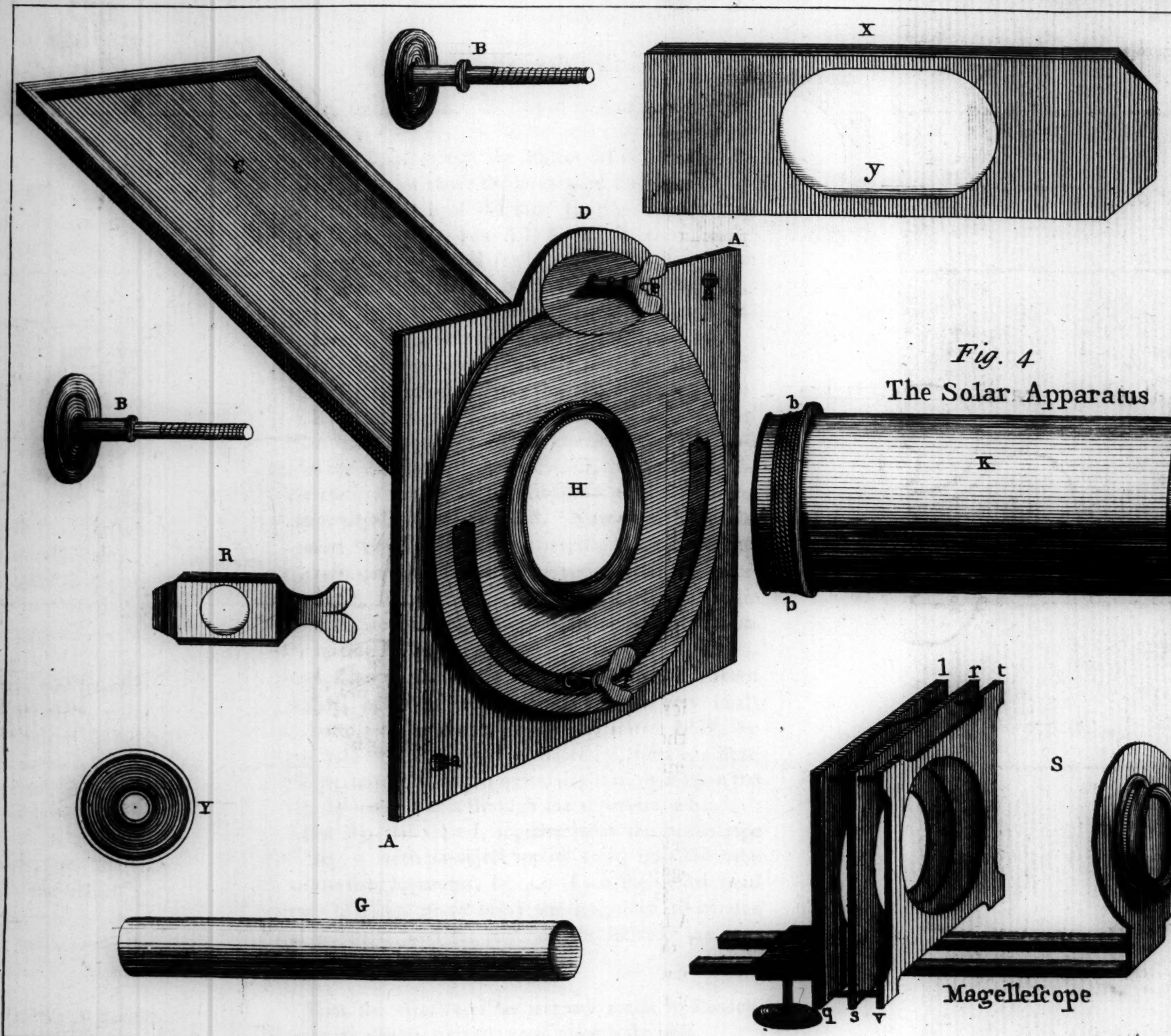


Fig. 4
The Solar Apparatus

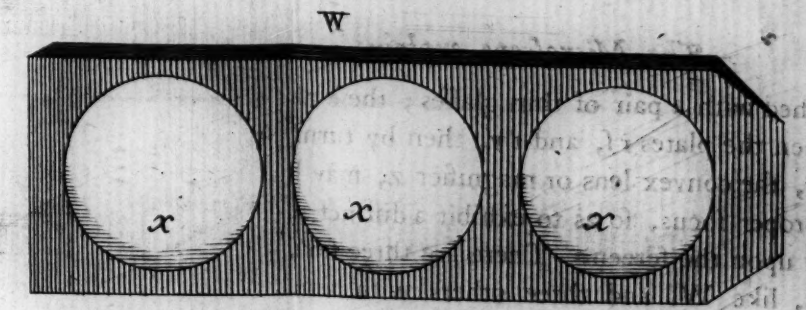
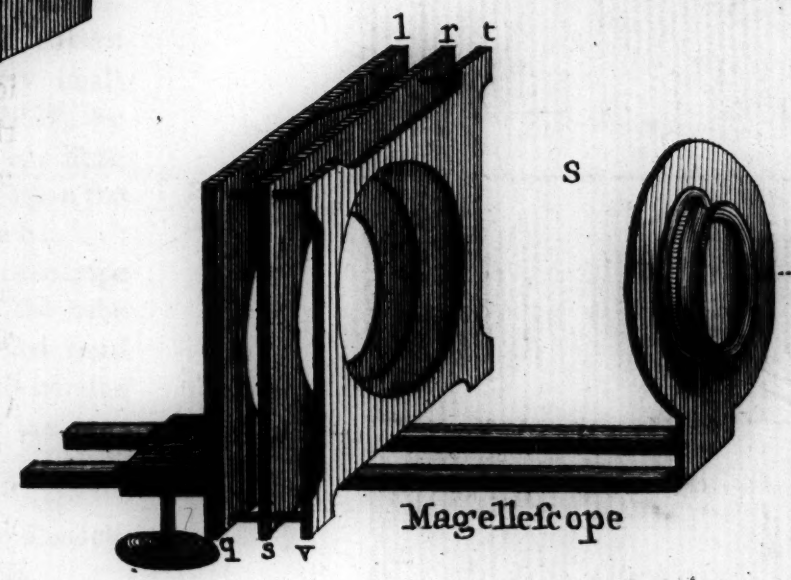
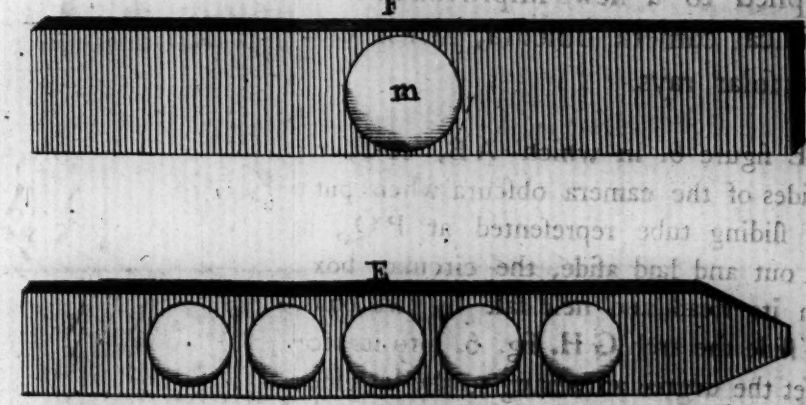


Fig. 5
The tooth & Pinnion Microscope



Magelllescope



you are in, to the point of the flower-de-luce at K, then tighten the screw at f, to fix the arch; by this means the axis I L upon which the mirror M N turns, will be properly elevated above the horizon of the place.

Screw the part b b of the tube K, fig. 4. into the inside of the top of the box A D F, fig. 6. there being a brass plate at F prepared for its reception: then screw the little tube M to the end N of the Microscope, N P, fig. 5. and put an object between the plates e d, g h, as before directed in the description of the solar apparatus.

Now set the camera upon a table placed nearly level in the sun shine, turn it about that the direction of the side E B may be nearly in the meridian; if you have no meridian line, a square magnetic compass box T V applied in the direction of the side C O, but to the back of the camera which is opposite and parallel thereto, and perpendicular to the side E B. Now turn the whole instrument together with the compass box, until the needle rests over the degree of its variation at the place you are at *, then the axis I L will be nearly parallel to the axis of the equator, and give an equatorial motion to the mirror M N.

Put a sheet of paper into the camera, and fix it there by wafers, wax, or needle points fixed in very small brass buttons. Elevate or depress the mirror M N, by taking hold of it at N, and if necessary, turn it a little sideways, until you obtain a round spot of light upon the paper, by looking at it through the aperture, a b c.

Then slip the tube I, together with the microscope N P, fig. 5. with an object applied to it, into the tube K of the solar apparatus, fig. 4. Turn the milled head screw O, of fig. 5. to bring the magnifier to its due focal distance, from the paper on the inside of the bottom

* Note, the variation of the magnetic needle in London, is about 21 degrees from the north towards the west.

tom of the camera, and you will obtain a lively image thereon.

Now shut the doors R S, sit down with a pencil in your hand, button the band m n upon your wrist, place your forehead close upon the cushion a b c, with your nose on the outside at a, that you may be able to breathe the free air; and by this means you may make an exact drawing of every microscopic object that you chuse to convey to posterity, or to oblige your friends with your own remarks thereon.

As the sun appears to move continually towards the west, the brightness of the light which surrounds the image of the object will diminish on one side, then turn the milled button I, fig. 6. extremely slow the same way with the sun's apparent motion, and you will have the same brightness as before. This must be occasionally repeated, by which an intelligent reader will instantly discover, that we have after the above preparation but one single motion to attend to, in order to preserve a proper illumination upon the image of the microscopic object intended to be drawn, until its out-lines are complete. From this valuable improvement, all scientific persons, whose knowledge prompts them to relate such discoveries as their researches engage them in, will be enabled to explain themselves much better by a picture of what they may be describing, which they may make themselves, without the assistance of a draftsman, and may by proper letters of reference convey their own ideas in such an extensive light, that is beyond the power of the most elegant writer, who, without a drawing, has, or may attempt to make himself understood.

As we have in this construction but one motion to attend to, in preserving a proper illumination upon the image of the object, much time and trouble is saved: whereas in all the former constructions there are two motions to be attended to, and that with very much difficulty,

faculty, even so as to make it tiresome to the operator, which is here removed. *

The circular box A D F, is represented at fig. 6. in the most convenient position for use, the axis I L being over the drafts-man's head, in which case his back must be turned toward the south, which will oblige him to sit between the window and the instrument, if the upper sash can be pulled down, but if the under sash is only moveable, the box A D F must be changed, so that the axis I L may be over the back of the camera, then the instrument may be pushed close to the window, and consequently the drafts-man's back will then be turned to the north; but if a large garden or open plain be near the house, it will, when the weather permits, be better to sit out of the house, where no buildings or other obstacles can intercept the sun's rays, whence we shall have no interruption from the jambes between the windows, &c.

The use of the new improved microscope, applied to the new pyramidical camera obscura, when illuminated at NIGHT by a peculiar lamp contrived for that purpose.

THIS useful invention is the result of a great many experiments that have been made for some years past, to illuminate microscopic objects in winter evenings, which has succeeded far beyond our expectation. And although we have applied it to the pyramidical camera obscura, as being the best form for these kind of experiments, yet they may be performed in a box of any

* Note, in this application of the solar microscope, we intirely omit the square plate A, the mirror C, and screws B B.

any other shape, let its form be what it may; but not with so much satisfaction.

Take off the circular head A D F, fig. 6. and then the upper part A D w r of the pyramid, fig. 6. set the last aside. Take out the grey glass which is placed in the inside of the lower part of the camera when it is not in use, and put it into the hole p q, which is represented at fig. 7. and then put on the cover Z Y; screw it fast by the two screws, one of which is seen at e, and place the circular box A D F upon the cover Z Y, and bolt it fast; then lay it upon a table as it is represented in fig. 7. the apparatus fig. 4. and microscope fig. 5. with the object intended to be examined being first prepared and placed within the box A D F, take the tube E F, with its semi-circle from the pillar A, fig. 2. (it separates at N) and screw it to the end F, of the circular box A D F, fig. 7. the rim with the oiled paper being first removed. Now light the lamp and suspend it on the ears G H. Sit down at the table and look at the grey glass p q, and you will there see a beautiful image of the object you have placed in the microscope. After having adjusted the magnifier to its proper focal distance, by turning the screw O, in fig. 5. and shut too the doors R S, of fig. 6. in this situation you may draw the out-lines of the object in the most correct manner, although the person is not accustomed to drawing. It may be first drawn upon the grey glass p q, and then covering that with paper, and holding it against the light, it may be finely copied upon the paper: or if you do not chuse to draw it twice, place a piece of thin paper, vellum, &c. upon the glass p q, and it may be drawn at once.

The representation of microscopic objects in this easy manner without the light of the sun, is extremely entertaining, as they appear in the highest degree a very fine picture. By this means we have obtained a very valuable

The Camera Obscura and Solar Microscope.

By George Adams,
Nº 60 Fleet Street London.

Fig. 6

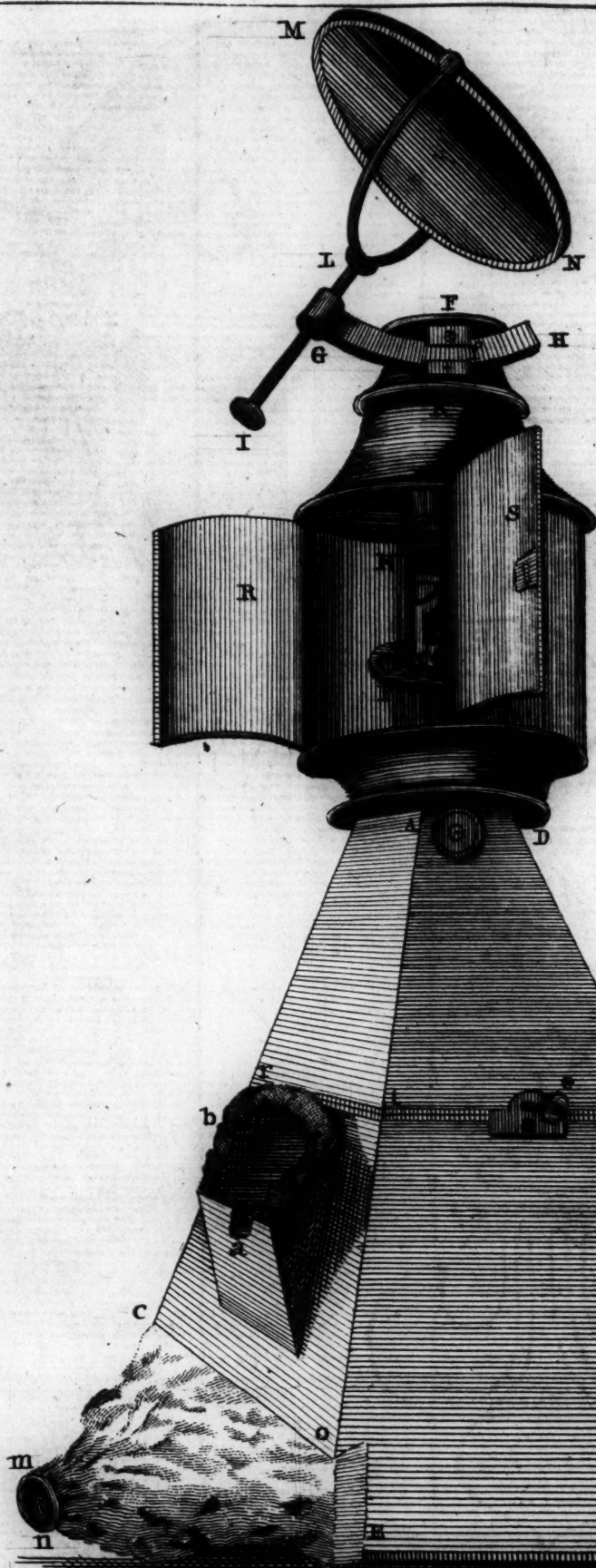
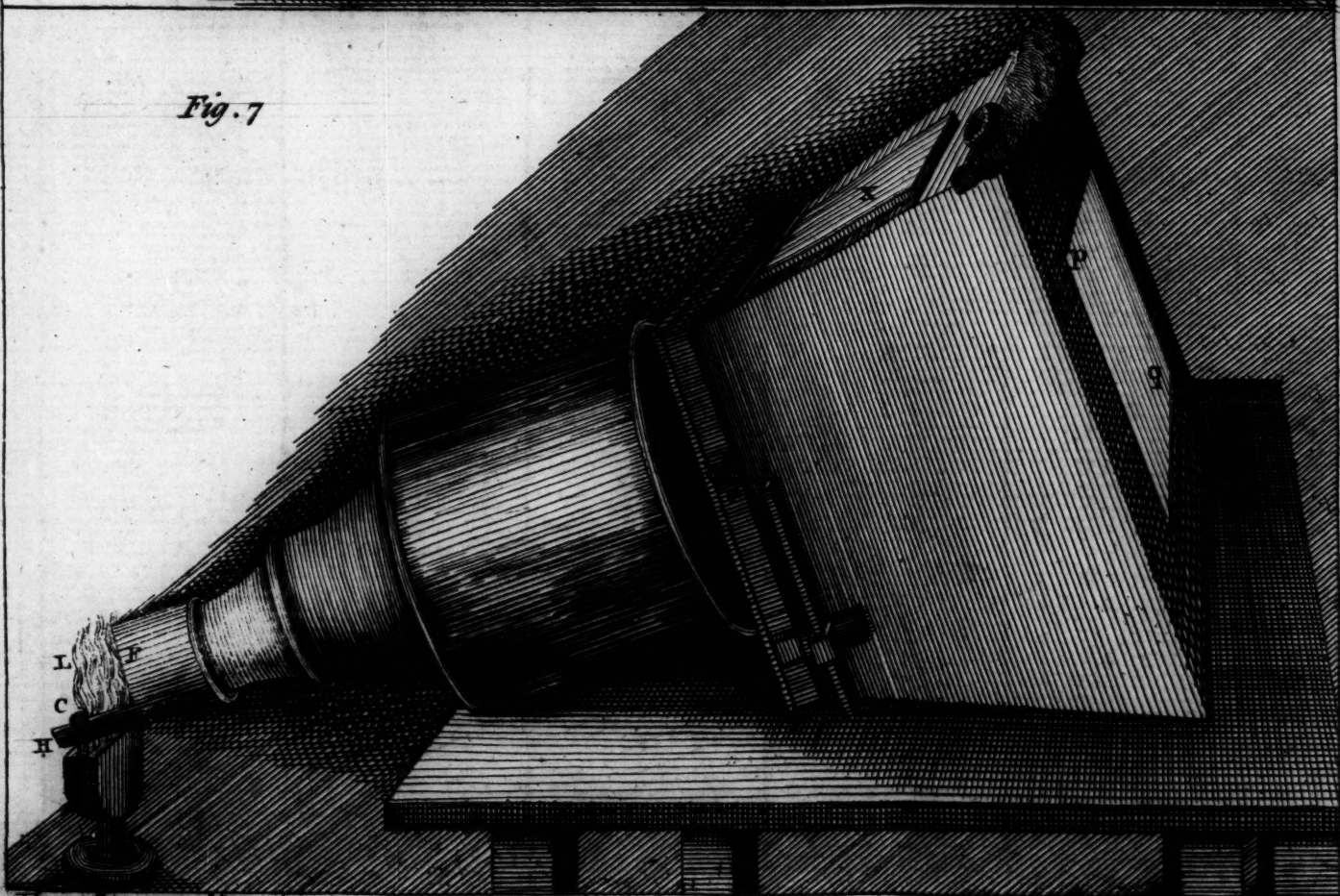


Fig. 7



ble acquisition of having it in our power to keep drawings of those beautiful appearances, which require no more trouble, than that of tracing the lines with a pen or pencil.

The use of the pyramidical camera obscura, in designing and taking perspective views.

A CAMERA obscura, is any dark place, wherein objects exposed to broad day light are represented upon paper, or any other proper white body, in their true proportions, with all the liveliness of colours, and diversity of motions, amazingly pleasant to behold. The advantages arising from the use of this instrument, to draft's-men in general, are so great and so well known, as to need no enumeration. Therefore we shall only add, that it is of very great use in giving the proportionable size of every separate object, or separate groups of objects in the same picture; by which means they may be copied after nature in the most perfect manner, and that constant difficulty removed, which requires so much time and study to give the several objects their true bigness and proper situation in the picture from the same point of sight.

There are two double convex lenses in square mahogany frames; one of which is to be used for distant, the other for near objects. They are to be put into the square sliding tube P Q, fig. 8. at d under the mirror r, their foci is marked upon each frame.

The pyramidical form of this instrument is allowed by a number of gentlemen who have experienced its utility, to be superior to those of any other construction hitherto made, having every desired advantage to exclude the light, and when you have done with it at any time, it is readily put up into a portable size.

Fig. 8.

Fig. 8. represents the pyramidical camera obscura mounted for taking perspective views, from any prospect the draftsman has a desire to imitate. After having chose the spot or point of sight from whence he would make his perspective picture, let him cause a table to be placed there, and set the camera upon it. Let him sit down before it, turn his back and the camera together, while he is looking through the apperture *abc*, until he finds the most agreeable picture he can obtain (from that point of sight) upon a sheet of paper already placed on the inside of the bottom of the instrument for that purpose. This being done, place your forehead close to the cushion *abc*, with your nose on the outside at *a*, that you may be able to breathe the free air, having first buttoned the band *mn*, upon your wrist; then proceed with a pencil in your hand to trace the out-lines of every object in your landscape, which will, when completely shaded, be a true representation of that perspective view. Your out-lines being finished, take out the drawing; put another clean paper into the instrument, it standing in the same place; sit on one side of it that you may look into the camera occasionally, and then you may shade your drawing agreeable to nature.

From the preceeding experiments and various trials made before the instrument was compleated, to exhibit microscopic objects by the help of a lamp without the sun, the two following curious applications of the camera obscura offered themselves, which we could by no means reject.

Fig. 9. represents the pyramidical camera obscura placed horizontally upon a table; the mirror *r* in fig. 8. being taken out of the square sliding tube *PQ*, and the flat cover of the said tube taken off, we put one of the convex lenses into the groves made for that purpose, near the end of the square tube at *P*. fig. 9.

Direct
L

Direct your instrument to any external objects and if your room is a little darkened, you will have an extremely vivid and beautiful picture upon the grey glass at r q fig. 9. But inverted, the outlines may be nicely traced with a black-lead pencil upon the glass, which being taken out and covered with a paper and held against the light, may be nicely copied, and afterwards shaded by the picture upon the glass, when put into its place, the black lead lines being first wiped off, with the corner of a napkin a little wet.

Note, this second form of the camera obscura hath the following advantages; first, as the picture is formed immediately, by the rays passing thro' the convex lens without any reflection, the objects are extremely vivid; and although the outlines must be traced in its inverted state, yet when the glass is taken out and turned the other edge downward, every part of the picture will have its proper attitude.

Secondly, a very great advantage arises from this application of the instrument, in diminishing large drawings or paintings to a smaller size, viz. Set the original painting upon a chair against the wall, but topside turvy, and you will have a lively representation of it upon the grey glass in an erect position; and if the room be long enough, a whole length picture may be taken in, and the representation may be either larger or smaller, as you either remove the instrument, or picture, farther from or nearer to each other; the change of the convex lens will do the same thing. When this operation is performed, the picture to be copied should be placed near a window, and you should sit with the instrument, next a remote window, and shut the shutter of that or those windows which are behind you, to exclude the light as much as possible, from falling upon the grey glass q r.

Thirdly, portraits may be correctly out-lined in this position of the instrument; and the greatest possible like-

ness obtained. Side-faces in imitation of shadows, are likewise taken this way to great advantage.

Let the person, whose portrait or side-face is desired, sit on a chair, at the distance the picture was placed at, and keep himself as still as possible.

The human attitude, in any position, may be admirably well delineated after the same manner.

Fourthly, pieces of still life, such as flowers, fruits, dead game, &c. may be elegantly copied this way, by setting them upon a stool, that is lower than the table, and pointing the instrument to your object.

All sorts of furniture, workmanship of every kind, such as mathematical instruments, models, busts, china, or other images, &c. may be also delineated in the same manner.

The third application of the camera obscura, is to represent objects in their natural situation without reflection. The preparation for this is as follows: take out the square sliding tube P Q, and place that convex lens, which is marked with No. 4. into that end of it which is also marked No. 4. and goes into the camera; then replace it again, as it appears in fig. 9. and put the tube W Z into the hole at P, until the shoulder m n, rests close to the surface at P, and the instrument will be ready for use.

In this structure of the camera, it may be applied to all the experiments, related in the preceding application; but the field of view will not be quite so large; yet in this we have many advantages, from the objects appearing in their natural situation.

See fig. 8. in which A D E B represents one side of the pyramidal camera obscura; A C O, the front; P Q, a square tube, which may be moved higher or lower, by turning the knob at f, in order to adjust the focus of the convex lens placed at d, to make a distinct picture at the bottom of the instrument; a b c is the opening,

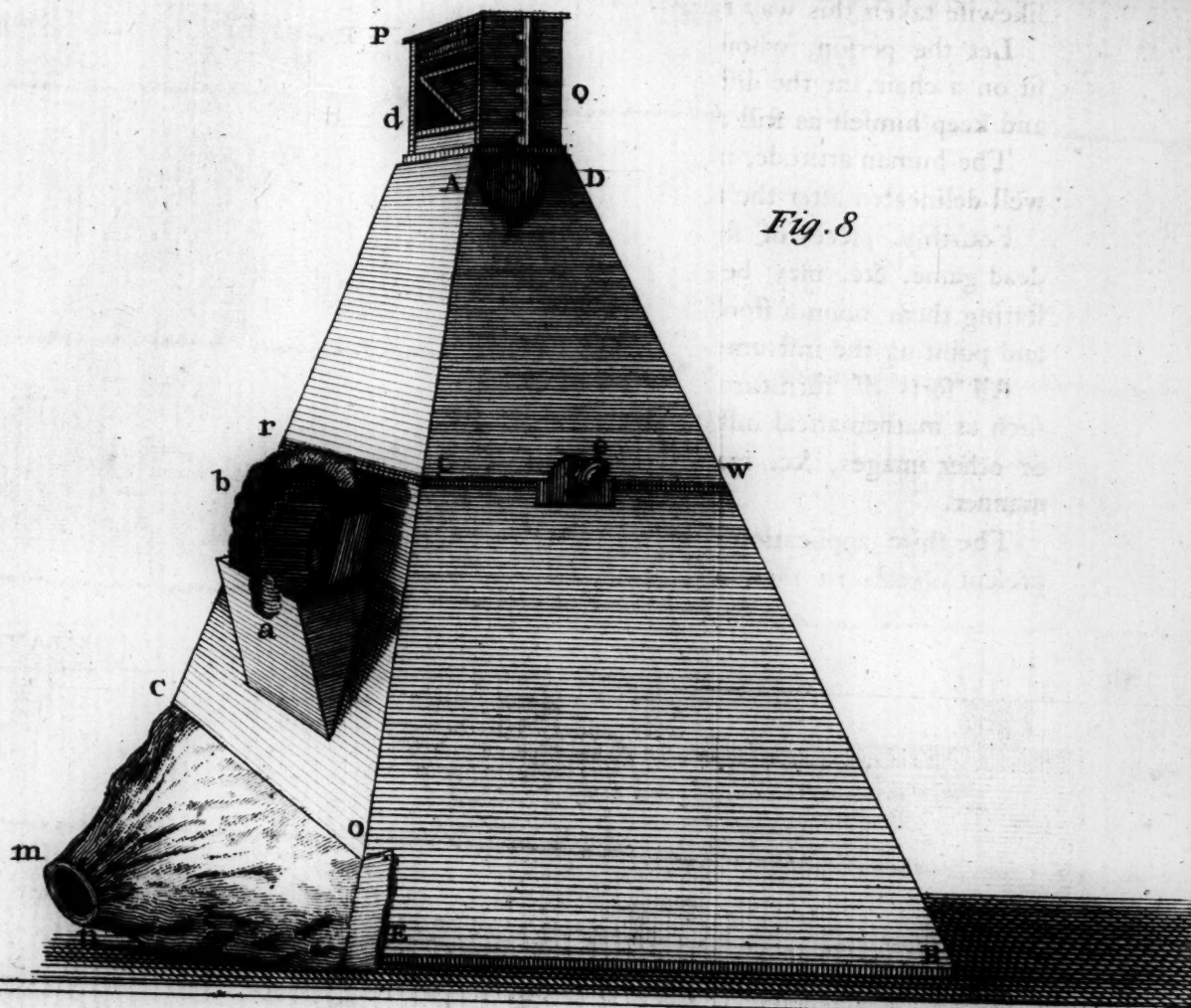
Camera Obscura By George Adams N^o 60 Fleet Street London

Fig. 8

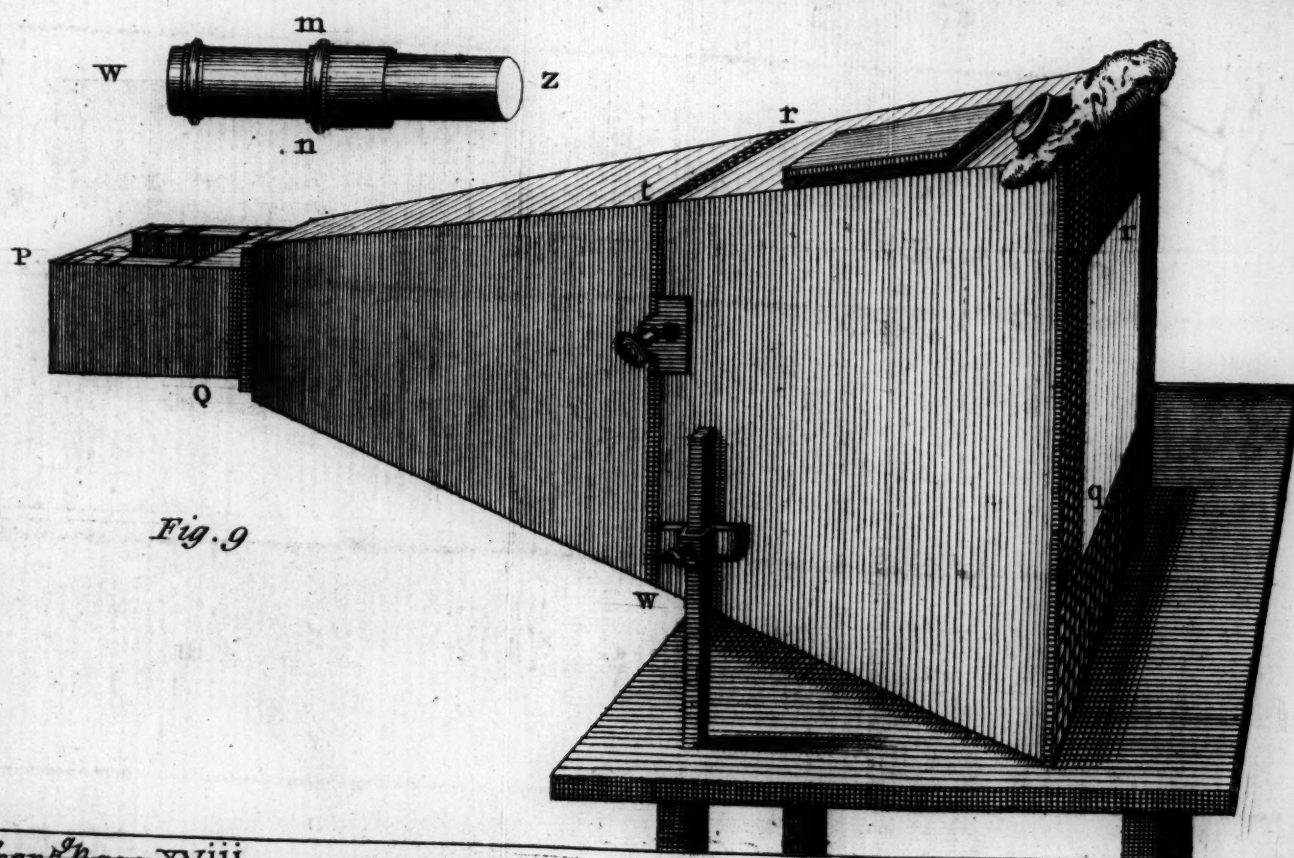


Fig. 9

opening, where the face is to be applied : C O E m n, is a sleeve of cloth ; m n, the wristband to be buttoned up on the wrist, when you trace the out-lines of any landscape.

When you have done with the instrument at any time, push the square sliding tube close down ; take off the upper part A D w t r, turn the small end downwards, and put it into the lower part r E W. Take off the face piece a b c, put it into the box, and cover the hole it leaves with a slider. Push in the sleeve, and cover it with the slider prepared for that purpose, and the instrument will be preserved from dust, after you have covered it at the top.

Note, all the small parts may be included in the lower frustrum r B, and in the circular head A D K, or they may be packed in a separate box.

The double constructed microscope.

A B C, fig. 10. represents the body of this microscope ; it contains an eye-glass at A, a broad lens at B, and a magnifier set in a button, which is screwed on at C ; one of these buttons is represented by itself at Q. There are six of them belonging to this microscope, which are numbered 1, 2, 3, 4, 5, 6, the least number being the greatest magnifier.

The body of the microscope A B C, is supported by an arm D E, into which it may be put or taken out at pleasure. This arm being fixed to the sliding bar F, may be raised or depressed to any height within its limits, upon the main pillar a b, which being fixed in the box b e, is by means of the brass foot d, screwed upon the mahogany pedestal X r, in which is a drawer at w, containing all the apparatus.

When the upper surface of the arm D E, is placed to that number on the fixed bar a b, which corresponds to

the number of the magnifier then in use, the distance of the magnifier from the object will be nearly right, fix it by tightening the screw *f*, after which you may adjust it to fit your sight, by turning the mild head *c* of the screw *c g*.

p q is the stage or object carrying plate, with a hole in its center at *n*; *G* is a mirror, that may be turned into any direction, so as to reflect the light of the sky, the sun, or a candle under the object.

H, a convex lens, for illuminating opaque objects; *L* is a cylindrical tube open on each side, a concave silver speculum *h* is screwed to its lower end. This cylinder is to be put over the snout *E C*, when an opaque object is to be examined, and its upper end set to the number of the magnifier in use, then the light will be thrown upon it by the mirror *G*, will be returned back upon that side of the object next the eye of the observer.

P is a cylindrical tube, in which an inner tube is forced upwards by a spiral spring. Its use is to receive an ivory slider *K*, in which objects are preserved between two moscovy talcs, or a glass slider, upon which any casual object may be laid: either of these are to be put between the plates *h* and *i*, and the cylinder *P* put into the hole *n* in the stage. The hollow at *k* is to receive a glass tube *N*, in which is confined a small water animal, to shew the circulation of the blood: *x* is a wier screw, to assist in cleaning the tubes, or to discharge their contents.

R a cone to be put on under the bottom of the cylinder *P*, its use is to intercept some of the rays of light, when the first and second magnifiers are used.

S, a box containing a concave and plain glass, between which may be confined any small living insect, which being placed over the middle of the stage, may be easily examined.

T.

T, a plain circular glass to be placed over the center of the stage at n, to lay any objects on that may at any time offer, and a loose concave glass of the same size, being laid with its hollow side downwards, will easily confine any living insect.

O, a long steel wire with its pliers and point to hold or stick objects on, slips backwards and forwards in a short brass tube o, which by the button p, fits into the hole of the stage, and then it may be conveniently managed under the magnifier.

W, a little round ivory box to hold a supply of muscovy talcs for the sliders.

Z, a small hair brush to wipe any dust off the glasses, or to apply a drop of any liquid.

X, a pair of nippers to take up any object to be examined,

V, a small ivory cylinder with a hole passing through it, one end is black, the other white; it is to be stuck upon the point y, of the wire O y: its use is to examine opaque objects, by placing those of a dark colour on the white surface, and those of a light colour on the black surface. This piece with the pliers being applied to one of the holes in the corners of the stage, and the cylinder L, with the silver concave h, upon the snout EC, will shew an opaque object to advantage.

Y, a convex glass to be held in the hand, for looking at casual objects, in order to determine whether they are proper for a microscopic observation.

M, a fish pan, whereon to fasten a small fish, to see the circulation of the blood; its tail being spread across the oblong hole at the smallest end, and tied fast by means of the ribband fixed thereto, then by shoving the knob t through the slit m made in the stage, the fish's tail may be brought under the magnifier.

U is a plain glass to lay any casual object upon, or if it be a living object, cover it with the glass T.

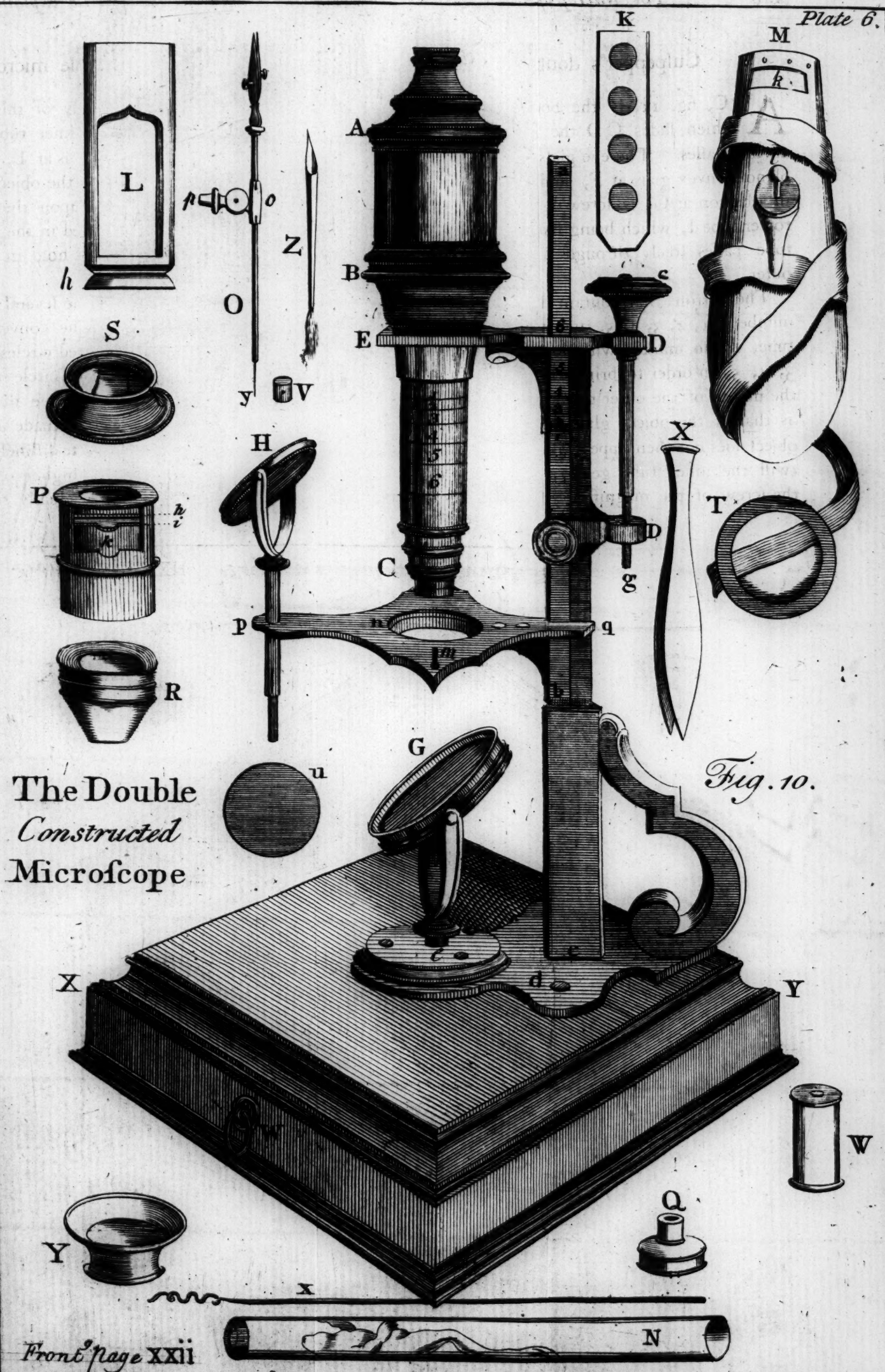
Culpepper's double microscope.

A B C, fig. 11. is the body of this microscope, in which slides C D the inner tube, that contains all the glasses. The eye glass is at E, the broad middle plano convex glass at F, and the object glass being set in a button at G, is screw'd upon the end of the narrower tube I, which being fixed in the base of the inner tube passes freely through a hole in the base of the outer.

The buttons that contain the several object glasses are number'd 1, 2, 3, 4, 5, and the convexity of the inner tube, is also marked with dotted circles numbered 1, 2, 3, 4, 5, in order to bring that circle to coincide with the mouth of the outer tube, whose number is the same as that of the object glass then made use of: but if the object does not then appear quite distinct, slide, or rather twist the inner tube gently, higher or lower, or turn the screw of the magnifier gradually till the object appears distinct. The greatest magnifiers are known by their having the smallest apertures.

The base B C of the outer tube is supported by three brass pillars on scrolls, fixt on a mahogany pedestal H K, in which is a drawer L, to hold the magnifiers and other parts of the apparatus. A little below the object-glass is fixed a plate M, like a stage between the pillars.

N, three small brass circles with holes through the middle of them which are to be placed over the hole in the middle of the stage, and then the ivory slider O may be put between the two uppermost, which are pressed together by a spiral springing wire lodged between the two undermost. The two outermost being held together by four small pillars passing through four holes in the circumference of the middle circle.



The Double
Constructed
Microscope

Fig. 10.

P, is a fish-pan to fasten a small fish on, to see the circulation of the blood, its tail being spread across the oblong hole at the smallest end ; then by shoving the button inwards through a slit made in the stage, a small brass spring under the stage will keep it steady ; for viewing it the tail may be brought exactly under the magnifier, by turning the pan on the button, or by shoving it inwards or outwards along the slit in the stage.

All transparent objects are well illuminated in this microscope, either by candle or sky-light reflected upwards from a concave looking-glass R, placed in a frame upon the center of the pedestal. While you are viewing the object through the microscope, turn this concave upon its horizontal poles a b, and you will soon find out that position of it wherein it reflects the most light through the hole c upon the object.

Opake objects when laid upon the plate s, which is on one side black ebony, and on the other a piece of white ivory, being laid over the hole c, in the stage, may be illuminated by the light of the sun-shine or a candle transmitted through a double convex lens a, which by turning on two screws, e, d, and the foot of it put into the hole f of the stage. The candle must be placed in a line drawn from the object through the middle of this lens at such a distance to be found by trial as will form the smallest spot of light upon the object plate. By daylight this glass is of no service.

T, an ivory cone to screw on to a male screw under the center of the stage : its use is to intercept some part of the oblique rays when the first and second magnifiers are used.

V, a glass tube to put a small frog or newt in, to see the circulation of the blood. When the object is well expanded on the inside of the tube, slide it over the hole c, in the center of the stage ; and bring that part of the object you would examine directly under the magnifier.

W, a cell containing a concave and a plain glass, is to confine fleas, lice, mites, or any small living objects, and being placed over the middle of the stage, may be viewed with ease.

X, a plain circular glass to be placed over the center of this stage to lay any objects on that may at any time offer, and a loose concave glass being laid with its hollow side downwards, will easily confine any living insect.

Y, a long steel wire with its pliers and point to hold or stick objects on, slips backwards and forwards in a short brass tube, which by the button fits into the hole of the stage, and then it may be conveniently managed under the magnifier.

O, a flat piece of ivory called a slider with four round holes through it, and objects placed in them between muscovy talcs.

Z, a little round ivory box to hold isinglass for the sliders.

U, a small hair brush to wipe any dust off the glasses, or to apply a drop of any liquid.

J, a pair of nippers to take up any object to be examined.

The screw-barrel, or Wilson's single pocket microscope.

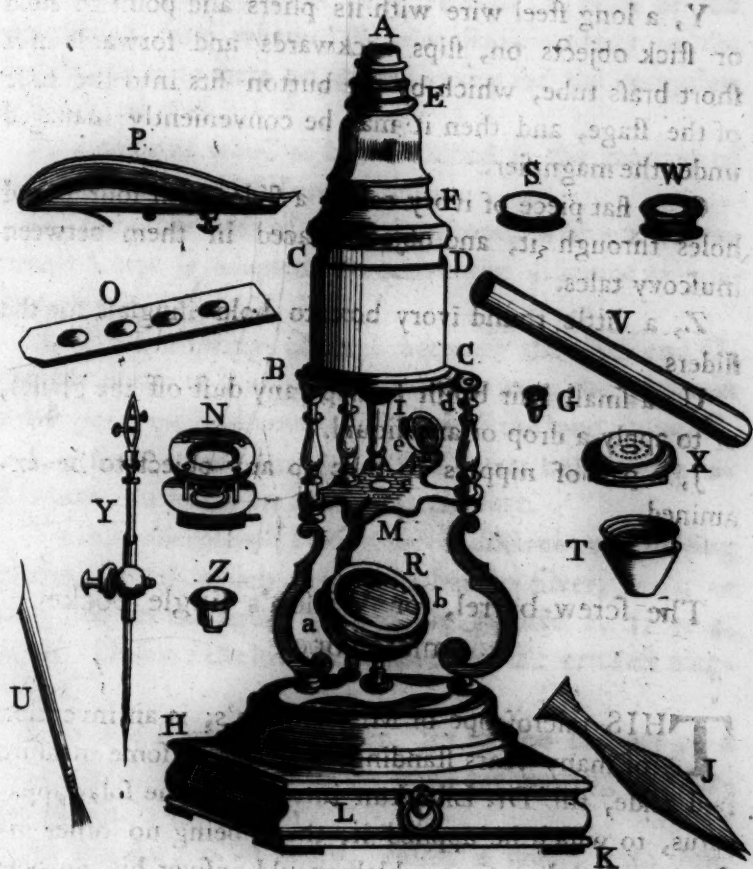
THIS microscope of Mr. Wilson's, is an invention of many years standing, and was in some measure laid aside, till Dr. Liberkun introduced the solar apparatus, to which he applied it, there being no other instrument at that time which would answer his purpose so well; since which time it has been revived, and esteemed, tho' very troublesome in many cases.

The body of the microscope is represented by A B, A B, fig. 12. made either of silver, brass, or ivory.

C C,

Culpepers double Microscope

Fig 11



is a long fine threaded male screw, that turns
the body of the microscope.
The object glass is the small flat glass, for
which may be placed, as occasion requires, one of the
two concave pieces of thin glass, with holes of different
thickness in the center of them, to cover the said glass,
and thereby diminish the aperture, when the greatest
magnification is used.
The thin plates of brass, within the body of the
microscope, one whereof is bent semicircularly in the
middle, to form an arched cavity for the reception
of a tube of glass.
A piece of wood or brass, arched in the manner of
the said tube, and fastened thereto.
The other end of the microscope, where a hollow
tube is added to receive the different magnifying
glasses, is fixed between the said end and C.
The tube of glass, intended to keep the plates in
contact, and connected against the long screw C.
A small turn of handle for the better holding the in-
strument, to screw on and off as picture.
The microscope body, for different magnifying
glasses, which are either in silver, brass, or
steel, and are marked 1, 2, 3, 4.
To picture the lower number is the greatest mag-
nification.
The seventh magnifier, is in the manner of a
ring, to be held in the hand for viewing any in-
strument, called a slip of ivory, with four
holes through it, wherein to place objects between
the two ivory slides, and one of brass, are usually
used with the microscope, some with objects placed in
them.

C C, is a long fine threaded male screw, that turns into the body of the microscope.

D, a convex glass, at the end of the said screw, on which may be placed, as occasion requires, one of the two concave pieces of thin brass, with holes of different diameters in the center of them, to cover the said glass, and thereby diminish the aperture, when the greatest magnifiers are used.

E, three thin plates of brass, within the body of the microscope, one whereof is bent semicircularly in the middle, so as to form an arched cavity for the reception of a tube of glass.

F, a piece of wood or brass, arched in the manner of the said plate, and fastened thereto.

G, the other end of the microscope, where a hollow female screw is adapted to receive the different magnifiers.

H, a spiral spring of steel between the said end G, and the plates of brass E, intended to keep the plates in a due position, and counteract against the long screw. C.

I, a small turn'd handle for the better holding the instrument, to screw on and off at pleasure.

To this microscope belong seven different magnifying glasses, six of which are set either in silver, brass, or ivory, as in the figure K, and are marked 1, 2, 3, 4, 5, 6. Observe the lowest numbers are the greatest magnifiers.

L is the seventh magnifier, set in the manner of a little barrel, to be held in the hand for viewing any larger object.

M is a flat slip of ivory, called a slider, with four round holes through it, wherein to place objects between two muscovy talcs.

Six such ivory sliders, and one of brass, are usually fold with this microscope, some with objects placed in them,

them, and others empty, for viewing any thing that may offer, but whoever pleases to make a large collection of objects, may have as many as he desires.

There is also a brass slider, not expressed in the figure, to confine any small object, that it may be viewed without crushing or destroying it.)

N, is a forceps, or pair of plyers, for the taking up of insects, or other objects, and adjusting them in the glasses.

O, a little hair brush or pencil, wherewith to take up and examine a small drop of liquid.

P, is a tube of glass, to confine living objects, such as frogs, fishes, &c. in order to discover the circulation of the blood.

When you would view an object, thrust the ivory slider in which the said object is placed, between the two flat brass plates; observing always to put that side of the slider where the brass rings are farthest from the eye; then screw in the magnifying glass you intend to use, at the end of the instrument G, and looking through it against the light, turn the long screw C C, till your object is brought to the true focal distance, which you will know by its then appearing perfectly clear and distinct. The way of examining any object accurately, is to look at it first through a magnifier, that will shew the whole thereof at once, and afterwards to inspect the several parts more particularly with one of the greatest magnifiers; for thus you will gain a true idea of the whole, and all its parts. And tho' the greatest magnifiers can shew but a minute portion of any object at once, such as the claw of a flea, the horn of a louse, or the like; yet by gently moving the slider that contains your object, the eye will gradually overlook it all; and if any part should be out of distance, the screw C C will easily bring it to the true focus.

As objects must be brought very near the glasses, when the greatest magnifiers are used, be particularly careful not to scratch them, by rubbing the slider against them, as you move it in or out. A few turns of the screw C C will easily prevent this mischief, by giving it room enough.

A scrole for fixing Wilson's pocket microscope, and reflecting light to it by a mirror.

A B C, fig. 13. is a brass scrole, which, for the better conveniency of carriage, is so ordered, as to take into three parts, and put into the drawer upon which it stands, with its reflecting mirror, and Wilson's pocket microscope.

The top part of the scrole is taken off at B, by unscrewing half a turn of the screw; then lift it up, and it comes out of the socket. The lower part unscrews at C, and the base unscrews at E.

The mirror lifts out at F, which with the scrole lie in one partition of the box.

To apply this scrole to use, fix the body of the microscope to the top thereof, by the screw A, as in fig. 13. by screwing it in the same hole as the ivory handle.

The brass or ivory slider being fixed as before described, and the microscope placed in a perpendicular position; move the reflecting glass D in such a manner, as to cast the light of the sky, the sun, or a candle, directly upwards, through the microscope; by which means it is made to answer most of the ends of a double reflecting microscope, hereafter to be described.

It is also rendered more useful for viewing opaque objects, by screwing the arm Q R, fig. 12. into the body of the microscope, at G, then screwing into the round hole R, that magnifier which you think will best suit
your

your object; and put the concave speculum S on to the outside of the ring R, you will find in the body of the microscope, between the wood or brass F, and the end of the male screw C C, a small hole U, through which slide the long wire T, which has a point at one end, and forceps at the other, that may be used occasionally, as your object requires: when you have fixed this, and your object on it, turn the arm R, which is performed by two motions, till the magnifier is brought over the object; it may be then adjusted to the true focus, by turning the male screw C C, in the same manner as before described. It must also be turned exactly over the speculum, by twisting the upper part of the scrole to one side, till your object, and the two speculums, are in one line, as will be found by trial, and then fix it by the screw B, at which time the upper surface of the object will be so exceedingly enlightened by the light reflected upward from the mirror, to the concave speculum, as to be seen as clear and distinct as any transparent one,

The manner of applying Wilson's pocket microscope to the solar apparatus.

THE solar apparatus having been already described, it remains only to shew how Mr. Wilson's pocket microscope is to be applied to it.

After having fixed the apparatus to the window-shutter, and adjusted it to the altitude and situation of the sun, so as to form a round spot of light on the screen.

Screw the tube K, fig. 4. into the middle of the plate A A at H, taking care not to alter the looking-glass, after it has been adjusted to form a round spot of light as directed before in the use of the solar microscope; then screwing the magnifier you choose to employ to the
end

end of your Wilson's microscope, at G, fig. 12. in the usual manner, take away the lens D, at the other end thereof, and place a slider, containing the object to be examined between the thin brass plates E.

Things being thus prepared, screw the body of the microscope A B, by the screw D, fig. 12. to the tube I at M, fig. 4. which slides into the tube K, and pull out the said tube I, more or less, as the object is capable of enduring the sun's heat.

The microscope for opake objects.

A, Fig. 14. is a fixed arm, through which passes a screw B, the other end whereof is fastened to the moveable arm C.

D is a nut fitted to the said screw, which when turned, will either separate or bring together the two arms A C.

E is a steel spring, that separates the two sides when the nut is unscrewed.

F, a piece of brass turning round in a socket, whence proceeds a springing tube, moving on a rivet, through which runs a steel wire, one end of which finishes in a point G, and the other end hath a pair of plyers R solder'd to it; these are either to thrust into, or to take up and hold any object, and may be turned round as required.

I, a ring of brass, with a female screw fixed on an upright piece of the same metal, which turns on a rivet, that it may be set at a due distance when the least magnifiers are used; and serves the screws of all the magnifiers.

K, a concave speculum of silver polished as bright as possible, in the center of which a double convex lens is placed, with a proper aperture to look through it:

on

on the back of this speculum a male screw L, is made to fit the brass ring I, which may be screwed into the said ring at pleasure.

Four of these concave specula of different depths, are fitted to four glasses of different magnifying powers, to be used as objects to be examined may require. The greatest magnifiers have the least apertures.

M, a round object plate, one side white, and the other black, intended to render objects the more visible, by placing them, if black, upon the white, and if white, on the black side. A steel spring N, turns down on each side to make any object fast; and issuing from the object plate is a hollow pipe to screw it on the needle's point G.

O, a small box of brass, with a glass on each side contrived to confine any living object, in order to examine it; this also has a pipe to screw upon the end of the needle at G.

P, a turned handle of ivory to screw into the instrument when it is made use of.

Q, a pair of plyers to take up any object, or manage it with conveniency.

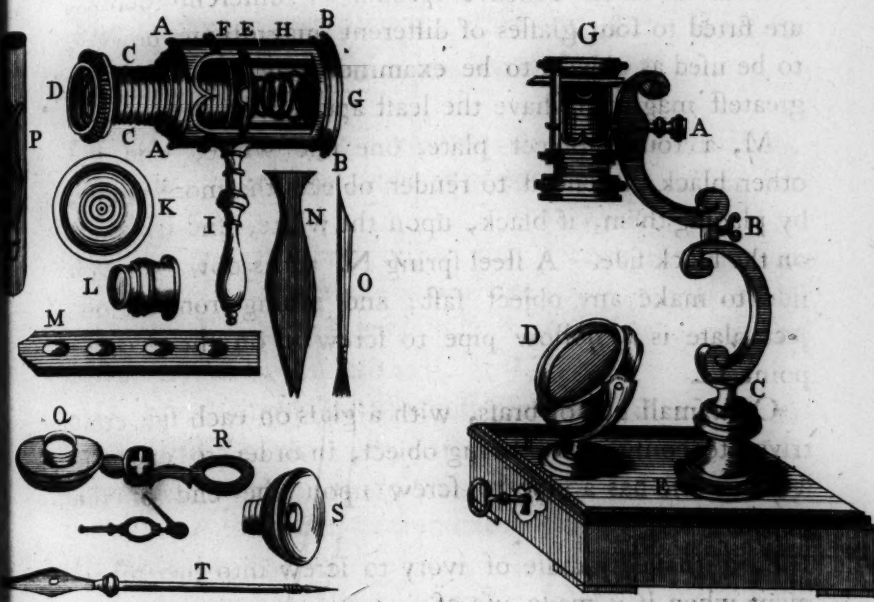
R, a soft hair brush to clean the glasses or specula.

When you would view any object, screw the speculum with the magnifier you intend to use, into the brass ring I, place your object either on the needle G, in the plyers H, on the object plate M, or in the brass hollow box O, as may be most convenient according to the nature and condition of it: then holding up your instrument by the handle P, look against the light through the magnifying lens, and by means of the nut D, together with the motion of the needle, by managing its lower end, the object may be turned about, raised, or depressed, brought nearer the glass, or put farther from it, till you hit the true focal distance, and the light be seen reflected
from

Wilsons Microscope

Fig. 12

Fig. 13



The Opake Microscope

Fig. 14



CONFIDENTIAL and

and very portable. It is the



from the speculum strongly upon the object ; by which means it will appear very distinct and clear.

The aquatic microscope, used by Mr. Ellis in his discoveries on corallines. *

THIS microscope is very simple in its construction, easy to manage, and very portable, as it lies flat in the pocket.

A, fig. 15. the brass pillar that screws into the top of the box K, this box contains the whole apparatus.

H, the shank and semicircle, in which the concave mirror moves on the two axis, at I, I.

D, the sliding pillar to adjust the silver dish with its lens at F F, to their proper focal distance. Note, this pillar D is now made to slide through the middle of the pillar A, for the convenience of being put into a less compass.

G, another silver speculum with a higher magnifier.

E, the arm that supports the silver speculum, is made to slide backwards, forwards, and sideways, so as to view all parts of any objects that may be laid upon the stage B.

C, a plain glass placed on the stage, with a black patch upon it for opaque objects, and also to lay all other kind of objects on, whether they be transparent or opaque.

M, a watch-glass to be placed on the stage B, instead of the plain glass C, for aquatic objects.

L, the nippers pointed at one end for different objects, or to receive on the pointed end the ivory cylinder N, for opaque objects.

O, pincers to take up small objects.

P, the brush to clean the glasses.

To

* See Ellis's essay towards a natural history of corallines.

To this microscope we frequently add a Wilfon's microscope, fig. 12. to which is fixed an arm like that at E, fig. 15. instead of the handle I, fig. 12. by this means we have a more commodious instrument than that before described, fig. 13. of fixing Wilfon's microscope and reflecting light to it by the mirror, because we have Wilfon's for transparent, and this aquatic for opaque objects.

But lately instead of applying Wilfon's, we have with greater propriety added the tooth and pinnion microscope, fig. 5. in one case with Ellis's microscope; by which means we have a more convenient instrument, that contains the principle apparatus of both, combined into a proper size for the pocket.

A single and double aquatic microscope.

THIS instrument has some advantages peculiar to itself. Fig. 16. and fig. 17. represent the principal part of the instrument; the first shews it erect, the second in an inclined position.

The magnifiers, No. 6. are to be placed in the ring, fg, of fig. 16.

i, l, k, is the stage or object carrying plate, upon which ivory sliders No. 9. or slips of glass not expressed in the plate, a round glass, or a concave glass No. 8. may be placed, each of them occasionally, and agreeable to the object intended to be viewed.

Upon one or other of these all objects are to be laid for examination.

r, t, s, is the mirror, to reflect light through any transparent object.

When either of the magnifiers is placed in the ring fg, fig. 16. and an object laid upon the stage i, l, k, it may be brought nearly to its focus, by discharging the screw

M^r Ellis's Aquatic Microscope

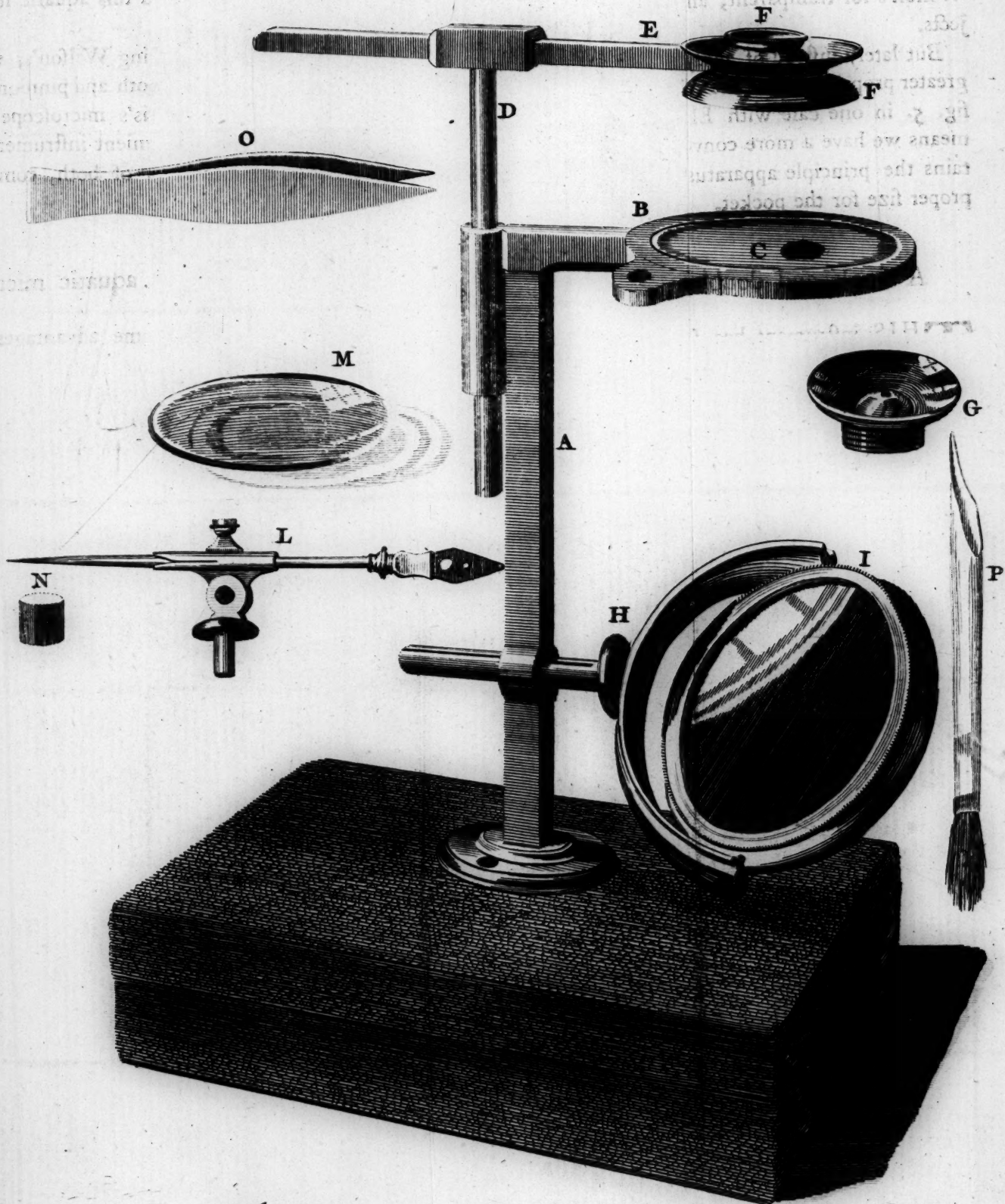


Fig 15

screw n, and sliding the bar b, c, higher or lower; then by refixing the screw n, and turning the screw p q, you may obtain the true focal distance of the magnifier then applied.

Ivory sliders and glass plates, &c. may be laid across the aperture i l k of the stage, when the microscope is in a vertical situation, but when it is inclined as in fig. 17. recourse must be had to the clip b c d, No. 10. its shank d, a, is to be put into the socket l on one side the stage, and push'd down upon the slider, glass plane, &c. so as to keep it from slipping off when the instrument is inclined.

A small fish or frog may be tied on one of the glass planes, or it may be confined thereon by the clip, No. 10. when the circulation of the blood is to be observed.

a, b, No. 11. are the nippers pointed at one end for different objects, or to receive on the pointed end the ivory cylinder, No. 12. for opaque objects: this is to be applied to the microscope, by putting the stem c, into the hole m, fig. 16.

There are six magnifiers to this microscope; one of them is represented at No. 5. another at No. 6. they are to be screwed into the ring, f g.

By means of the shank f h, of the ring f g, which slides backwards and forwards in the piece h z, and by the assistance of the joint at z, the magnifier may be brought over any part of the stage, l, i, k; the screw at y, will fix the magnifier, when it is found convenient.

There are two silver specula to this microscope, one of which is seen at No. 13. each of them contain a magnifying glass; their use is to illuminate opaque objects; these are to be screwed into the underside of the ring, f g.

No. 14. is a little barrel, with a lens to be used in the hand, or screwed into the ring f g.

No. 7. is a body containing two lenses, by the help of which this instrument becomes a compound microscope, and is to be applied as follows; screw the part a, of the magnifier, No. 6. into the ring fg, of fig. 16. then screw the end e of the body, into the female screw in the upper part of the button which contains the magnifier.

When either of the silver specula are applied to the body, No. 7. remove the ring fg, and put in a larger which is amongst the apparatus in the box. Then screw the double microscope above, and the silver specula underneath it. The body of the microscope may be lengthened, by putting up the tube a b, out of its case c d.

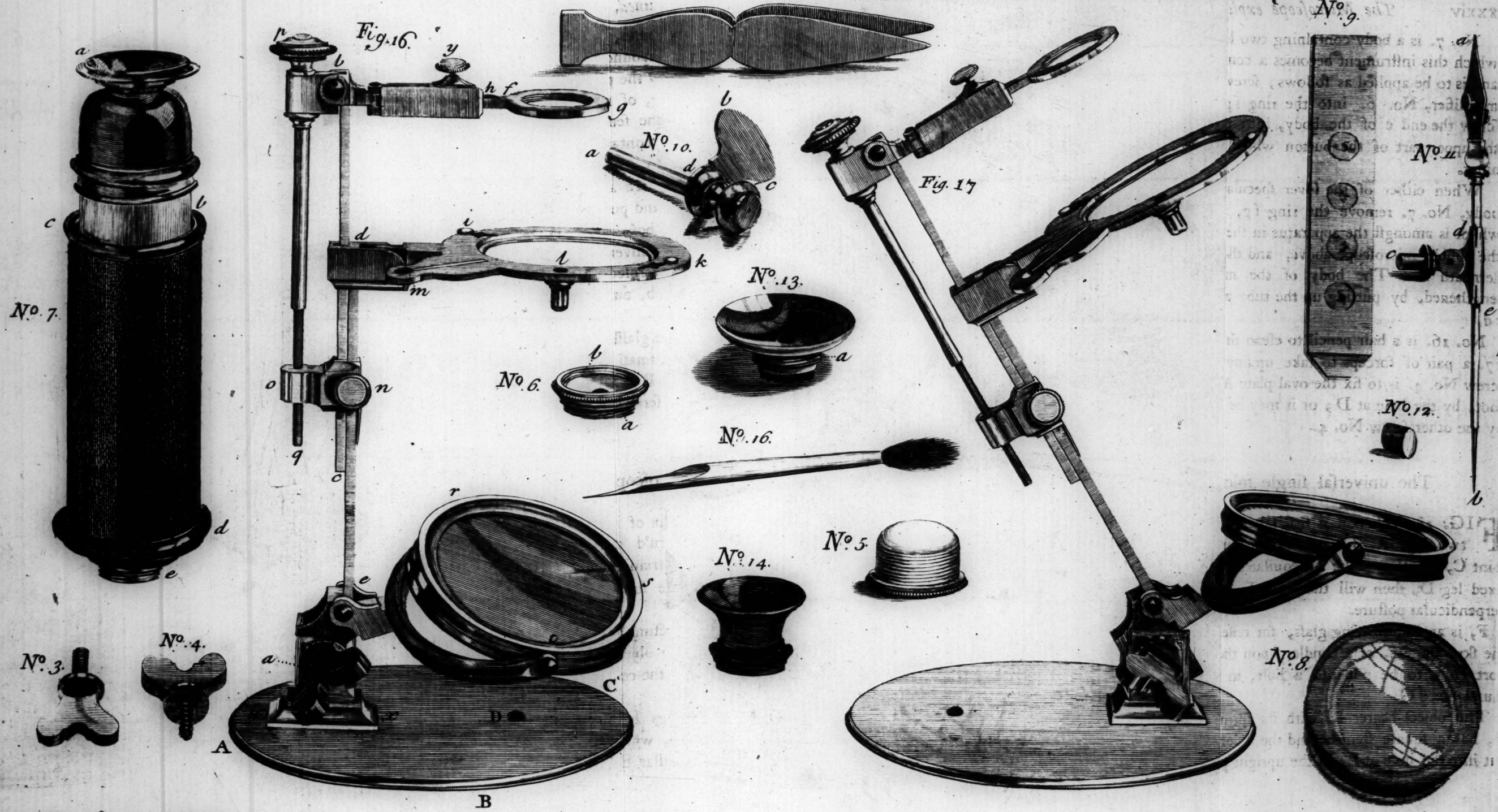
No. 16. is a hair pencil to clean the glasses, and No. 17. a pair of forceps to take up any small object; the screw No. 4. is to fix the oval plate A B C, to a wooden foot, by the hole at D; or it may be screwed to a table by the other screw No. 4.

The universal single microscope.

FIG. 18. When it is first taken out of its box, the two legs A, B, are to be turn'd about upon joint C, till they make an equilateral triangle with the fixed leg D, then will the pillar E, be supported in a perpendicular posture.

F, is an illuminating glass, for reflecting the light of the sky, the sun, or a candle, upon the object: its support H, is to be put into a hole, in the center of the round piece G.

The object-bearer I, with its springs b, and slider K, has a square stem behind the slider, which is to be put into the hole at L, in the upright pillar E.



M M M, is a scollop'd plate, which contains the six magnifiers, numbered from 1 to 6, the least number being the greatest magnifier; in the center, and on the underside of this plate, is a short cylinder, with a small steel pin near the end of it. This cylinder is to be placed in the top of the pillar E, in such a manner that the aforesaid steel pin may go into the slit at æ.

N, a black eye piece, hollowed out to defend the eye from the side rays of light, under which the magnifiers may be turned round at pleasure.

O, is a reflecting speculum of silver highly polished; which when an opaque object is to be viewed, must be placed under the eye-piece N. By which means, the light thrown upon it from the mirror F, will be by it collected and reflected back again upon that surface of the object next the eye; which will then be so strongly illuminated, as to be examined with ease and pleasure.

P, is an adjusting screw, by the turning of which an object placed between the object carrying plate I, and springs b, is readily raised or depressed; until it is brought into the exact focus of the magnifier.

1, 2, 3, 4, 5, 6, are marks on the pillar E, to shew the respective distances of the object from the magnifiers, according as each glass magnifies more or less.—For instance, if you use the 5th magnifier, first place it under the eye-piece N, and then with your finger and thumb turn the screw P, till the finger of the hand which is engraved on the sliding-piece Q, points to the mark 5 on the pillar; then will the object be very near its exact distance from the magnifier; so that by a turn or two of the screw P, either backwards or forwards, to be found by trial, you may soon fit it exactly to your eye.

The object carrying plate I, and steel springs b, are capable of holding ivory sliders, or other contrivances of different thicknesses, by unscrewing the little screw c, and with your nail pressing down the slider K, by the

button d, the steel springs will then be so separated from the plate I, as to receive any other part of the apparatus; and may be there made fast by tightening the screw c.

e, A nut, by the screwing of which the joint C may be tightened, if at any time it should wear easy.

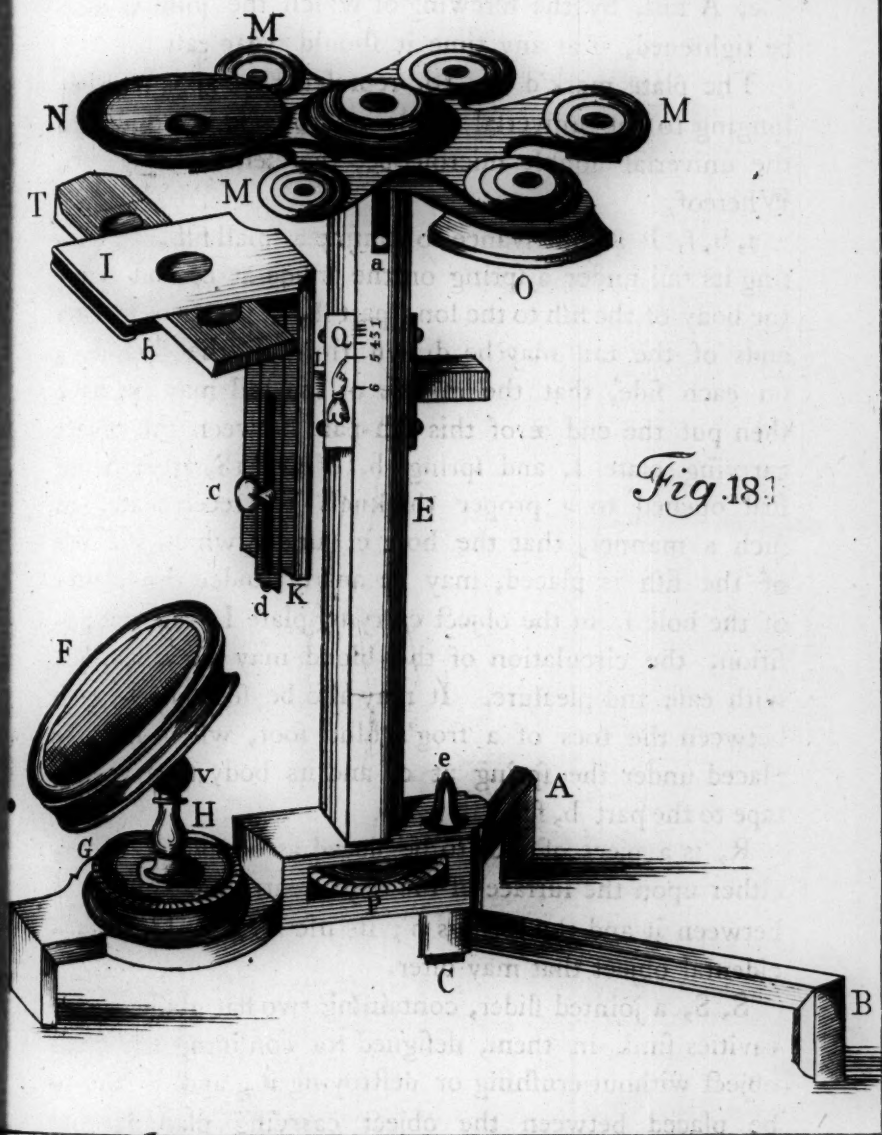
The plate mark'd fig. 19. represents the apparatus belonging to the universal single microscope; and also to the universal double microscope, represented at fig. 20. Whereof,

a, b, f, Is a contrivance to confine a small fish, by putting its tail under a spring on the inside at c, and tying the body of the fish to the long part b, f, the two extreme ends of the tail may be drawn through the slits d, d, on each side, that the middle of the tail may lie flat: then put the end æ of this fish-pan between the object carrying plate I, and springs b, of fig. 18, (they being first opened to a proper thickness to receive it,) in such a manner, that the hole e, under which the tail of the fish is placed, may lie nearly under the center of the hole f, in the object carrying plate I. In this position, the circulation of the blood may be examined with ease and pleasure. It may also be seen in the web between the toes of a frog's hind foot, which is to be placed under the spring at c, and its body tyed with a tape to the part b, f.

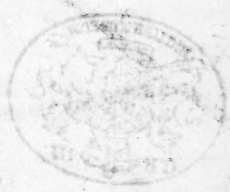
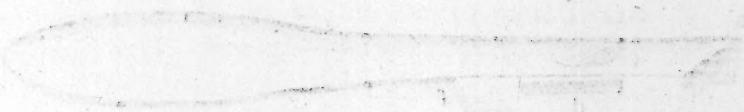
R, is a piece of glass to be placed as occasion requires, either upon the surface of the object carrying plate I, or between it and the springs b; its use is to hold any accidental object that may offer.

S, S, a jointed slider, containing two flat glasses, with cavities sunk in them, designed for confining any small object without crushing or destroying it; and is also to be placed between the object carrying plate I, and springs b, which must be set wider to receive it as before directed.

The Universal Single Microscope ^{Pl 11}

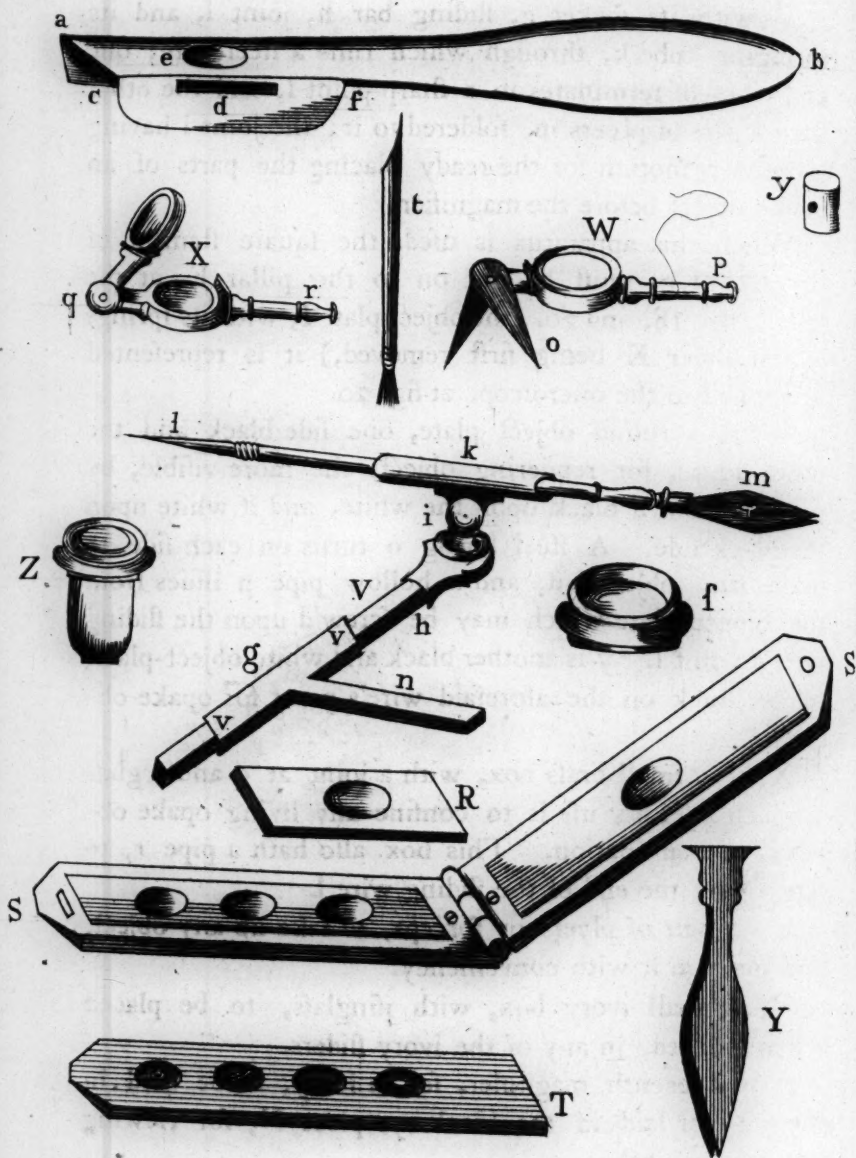


81. 118.



118. 118.

Fig. 19



T, is an ivory slider with four holes, wherein to place different objects between two pieces of muscovy tales, and is also to be applied between the object carrying plate I, and springs b, see fig. 18. with the ivory slider T, applied to it.

V with its socket g, sliding bar h, joint i, and its springing tube k, through which runs a steel wire; one end whereof terminates in a sharp point l, and the other hath a pair of plyers m, soldered to it: the joint i having a twofold motion for the ready placing the parts of an opaque object before the magnifier.

When this apparatus is used, the square stem n, of the socket g, must be put on to the pillar E, at the hole l, fig. 18. and 20. (the object plate I, with its springs b and slider K being first removed,) it is represented as applied to the microscope at fig. 20.

W is a round object plate, one side black and the other white, for rendering objects the more visible, by placing them if black upon the white, and if white upon the black side. A steel spring o turns on each side to make any object fast, and a hollow pipe p issues from the object plate which may be screw'd upon the sliding wire's point l. y is another black and white object-plate, to be stuck on the aforesaid wire's point for opaque objects.

X, is a small brass box, with a joint at q and a glass on each side, its use is to confine any living opaque objects for examination. This box also hath a pipe r, to screw over the end of the sliding wire l.

Y, a pair of plyers or forceps, to take up any object, and manage it with conveniency.

Z, a small ivory box, with isinglass, to be placed when wanted, in any of the ivory sliders.

f, is a seventh magnifier, set in ivory, to be held in the hand or laid in the black eye-piece N, for viewing any large object.

t, A little hair-brush or pencil, wherewith to wipe any dust from off the glasses, or to take up any small drop of liquid one would examine, and to put it upon the glass R.

The microscope being placed on a table near the window, direct the mirror F towards the sky, and then looking through the eye-piece N upon the object, placed next under the plate I, turn the illuminating glass F, so about upon its support H, and joint y, till the light is reflected upwards to the object.

When an opaque object is to be viewed, place the reflecting speculum O, exactly under the eye-piece N; fig. 18. and fix your object either on the point of the sliding wire l, in the plyers m, in the brass hollow box X, or on the object plate W, then apply this whole apparatus mark'd V, to the microscope, by putting its stem n into the hole L of the pillar E, the object carrying plate being first removed.

This microscope may be applied to the solar apparatus, by screwing the foot D of the universal microscope. fig. 18. upon the end of the tube M, fig. 4. as before directed, in the description of the solar apparatus.

The universal double microscope.

THIS microscope fig. 20. is composed of three double convex lenses, two of which are placed in the body thereof at a and b, and the magnifier at g, six of which belongs to this microscope, and are fixed in a scollop'd plate M, M, M, moveable about a center at f, by which means either of them may be readily turn'd under the other two glasses, as at g, whereby the trouble of searching out for different magnifiers is remov'd.

The body of the microscope is supported by the arm T, having a circular collar, whereinto it may be screw-
ed,

The Universal Double Microscope

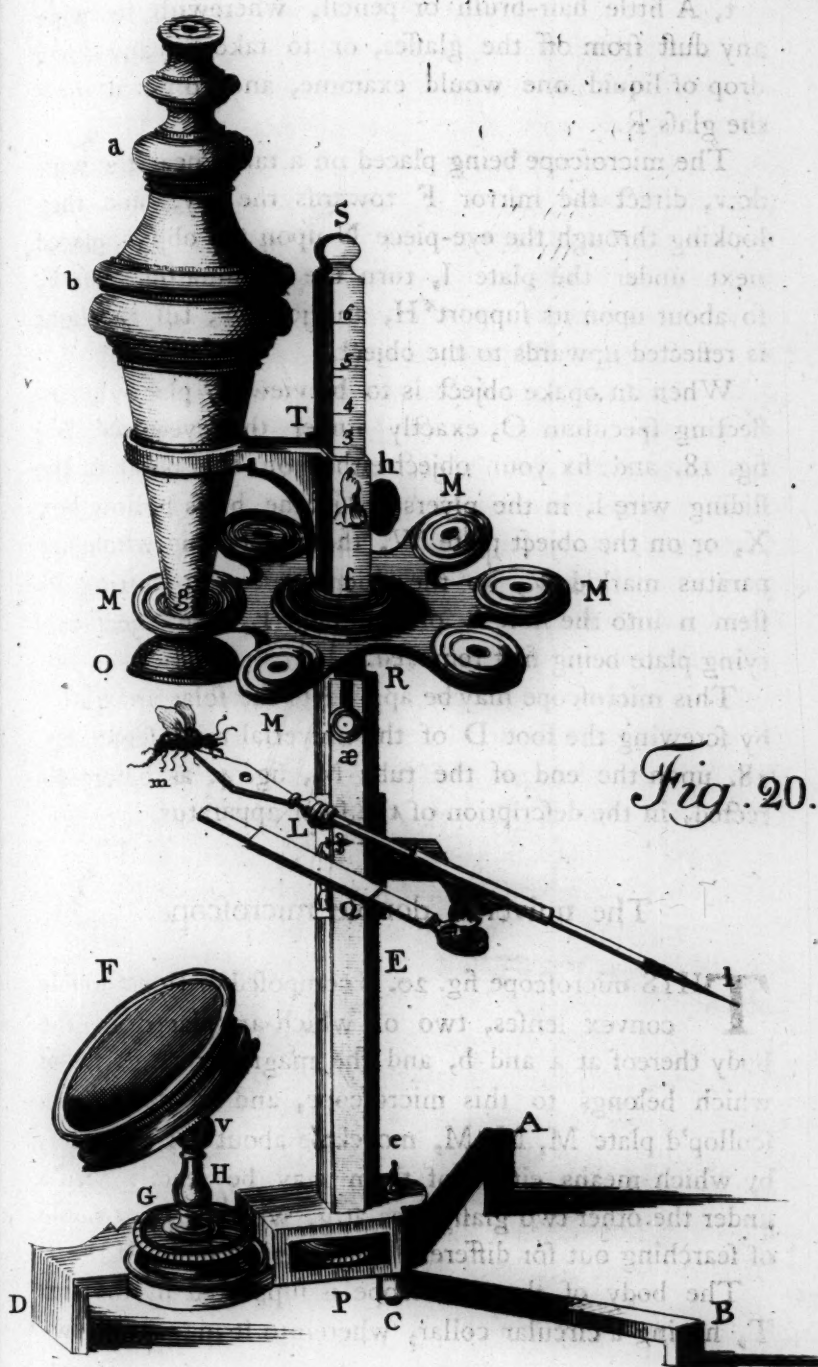


Fig. 20.

ed, or from whence it may be easily taken; this arm proceeds from the upper part of the sliding socket T, f.

The aforesaid socket T, f, together with the scollop'd plate M M M, and the body of the microscope, may be moved up or down the square bar R S, which is divided into as many parts (1, 2, 3, 4, 5, 6.) as there are magnifiers of different foci; so that the distance of the object from the object-glass may be found without any trouble, by setting the finger of the hand engrav'd upon the socket, to the correspondent number of the magnifier (the number under the body of the microscope) on the bar R S, and fixing it there by help of the screw h. But as it is scarce exactly enough determined this way, the object may be brought nearer to, or removed farther from the magnifier at discretion, by a turn or two of the screw P. Remembering at the same time, the upper hand is set to any number on the square bar, to place the index on the piece Q, to the flower-de-luce on the upright pillar E.

O, is a reflecting speculum highly polished, which must be placed at R, when an opaque object is to be viewed, on which a direct light becomes reflected from the aforesaid speculum.

The square bar R S, fits into the top of the upright pillar E, and may be made fast thereto by the screw at æ.

The object-bearer I, ivory slider, illuminating glass F, with its support H, and round piece G, and the apparatus V, with its nippers and sliding wire, &c. having been sufficiently described in the use of the single universal microscope, I shall refer the reader to that for the uses thereof, and also for a description of the apparatus, which is exactly the same as that represented in fig. 19. and its uses and application to this universal double microscope, the very same as in the foregoing universal single one,

A new compendious pocket microscope.

THIS instrument being an abridgment of the variable microscope, is contrived for the pocket, that it may be ready when gentlemen and ladies are amusing themselves in their gardens, parks, &c. to inspect, and collect such objects as may be proper to preserve for a future examination, to be viewed in the variable microscope, fig. 1. and 2. or to delineate them by help of the camera microscope, fig. 6. or 7. either in the sun shine, or in long winter evenings.

A B C, fig. 21. No. A. represents the body of the microscope, containing two eye glasses at A, a third at B, and a fourth glass between B and C, at the end C, is seen the dove-tail into which the brass slider F that contains the six magnifiers, is to be put. The numbers 1, 2, 3, &c. being placed at the extremity of the dove-tail at C, the magnifiers corresponding to each number, will then be under the center of the body of the microscope, the least number is the greatest magnifier.

This microscope in its compound state has the property of increasing the field of view and the light; as has been shewn in page ii. in the description of the variable microscope, as well as that of increasing the magnifying power of each particular magnifier.

The compound body A B C, is supported by an arm N O, into which at C, it may be screwed or taken out occasionally. This arm N O, slides backwards or forwards into the box P, which turns round on the top of the moveable pillar R, by which double motion every part of an object of the size of the stage D D may be readily examined.

The sliding bar R may be raised or depressed by turning the ivory head I, so as to adjust the body of the microscope

croscope with either of its magnifiers to their proper focus. This sliding bar R being connected with the bar X S, that is moveable upon a joint at S, the microscope may be thereby placed to any convenient oblique situation. W, is a key to tighten the joint at S, if requisite.

The joint at S turns horizontally in the center z of the triangular feet V V V, which support the whole instrument.

The stage D D slides into a dove-tail at e, in this the ivory sliders G are to be placed to examine such objects as are placed between the talcs; or all casual objects may be placed upon the flat glass K, when put into the stage, and examined with ease, or if they be animalcula in fluids, the concave glass L is to be applied to the stage D D, or if they be living insects, such as flies &c. first place the concave glass L upon the stage, and cover it with one of the flat glasses K, and you may examine it with pleasure.

Many objects may be viewed by being pinched in the nippers b, the stage D D being first removed, and the part d of the nippers b with its joint c, being put into the dove-tail at e: the whole of such objects may be turned round, and every part of them examined with pleasure.

The illuminating glass Q Q turns on the two axis n, n, and also at f, by which means it may be readily directed to a white cloud and reflect the light under any transparent object to the eye at E, and also to either of the concave silver specula M when an opake object is to be examined that the light may be thrown on that surface of the object which is next the eye.

When an opake object is to be examined, unscrew the dove-tail piece at c, and screw one of the silver specula M into its place; lay your object on one of the round glasses

glasses K or L, or place it upon the ivory cylinder at r, one side of which being black, the other side white, for a contrast to any object that may offer.

T, is a pair of forceps to take up any small object.

Remove or unscrew the body A B C, and screw in its place the black eye-piece H, and you will have an excellent single microscope to be used with all the above apparatus already described.

N^o. A.

A New compendious Pocket Microscope.

By Geo. Adams N^o 60 Fleet Street;

L O N D O N.

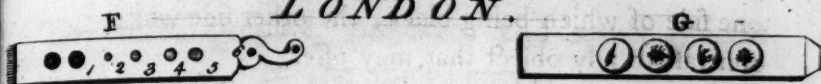
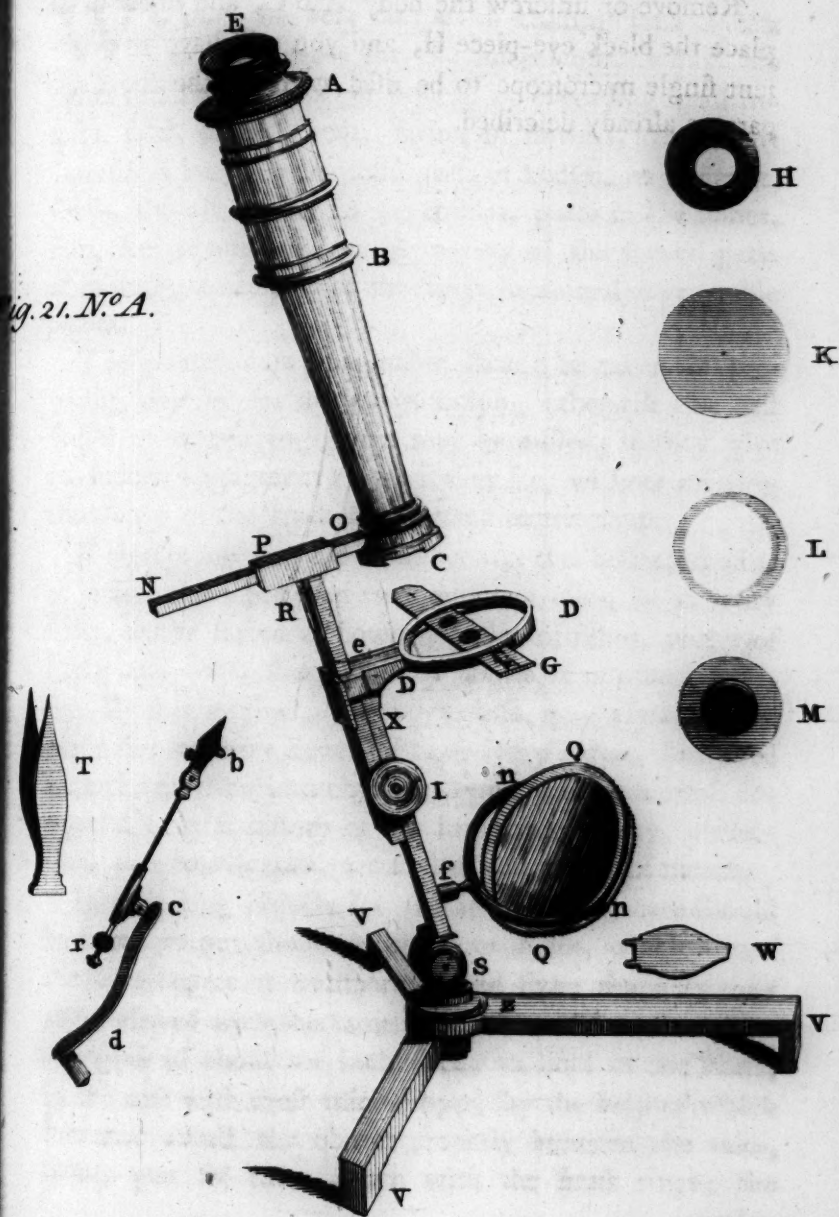


Fig. 21. N^o. A.



Wright sculp.

Front page. xlii

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To chuse, prepare, preserve, and apply objects
to the microscope.

WE must be very curious in chusing such objects as are proper for the microscope, which are either small parts of larger bodies, or exceeding small insects, salts, sands, seeds, farina of flowers, &c. or the interstices between the solid parts of bodies, as minerals, shells, the air vessels in vegetables, pores in the bones, skin, &c. of animals, or the motion of the several parts of minute animals, or of the fluids in animal or vegetable bodies.

The greatest care imaginable should be taken in preparing objects for an examination; otherwise the best skill'd in magnifying glasses may be misled, if they give too sudden a judgment on what they see, without assuring themselves of the truth by repeated experiments.

If objects are flat and transparent, the best method is to inclose them between two muscovy talcs, in an ivory slider, as the farina of flowers, scales of fishes, wings of butter and other flies, &c. the bodies of minute insects, &c. By this method, every virtuoso may always have ready two or three dozen of these ivory sliders, furnished with the most curious objects; which will be a most delightful natural history of the surprizing beauty, perfection, and contrivance, we find in the works of nature.

In collecting objects for the ivory sliders, care should be taken to put those into the same slider, which are of the same degree of transparency and size; that they may all be viewed with the same magnifier. There is a convex glass of about an inch focus to hold in the hand, in the case with most microscopes, by the help of which you may adjust the objects properly between the talcs, before you fix them down with the brass rings; the
number

number of the magnifier may be also marked on each slider its objects are fittest for. Many small living objects may be placed in this manner between the talcs, such as mites, or any other small insects which will remain alive several days. But for present examination, these, as well as larger objects, may be laid in the hollow of a glass slider, and that covered with a flat glass slider, or they may be pinched in the nippers, or stuck upon the point as occasion may offer.

The animalcula in fluids, may be examined in a small drop of water taken up with the head of a pin or a hair pencil, and placed in the hollow of a glass slider; if on viewing them, you should find them exceeding numerous (as is often the case,) that by their continual running over one another, their shape cannot be distinguished, some part of the drop must be taken off the glass, and a little fair water put to the rest, which will separate, and make them appear distinct. It is necessary thus to dilute, with fair water, the semen masculinum of all animals; otherwise their shape cannot be discovered, they are so crowded together in such infinite numbers.

If salts in fluids are to be viewed, you must let the fluid evaporate, that the salts may be left behind upon the glass, and be more easily examined.

For viewing the circulation of the blood in the tails of fishes, in frogs, newts, &c. they are sometimes put into glass tubes, or tied upon one of the glass slips or upon a fish-pan which is made to some microscopes, or by the frog frame in the messentry of a frog to the highest advantage, as will be hereafter shewn.

Patience and dexterity are required to dissect insects, and view their internal structure, which will be easily done with a fine needle and a lancet; if they are placed in a drop of water, their parts will then be separated with

with ease; and the stomach and bowels lie plainly (before the microscope) to be viewed and examined.

Bits of different colour'd glass are necessary for this purpose, to place objects on, because many objects are much more distinguishable when placed on one colour, than on another. Glass tubes of all sizes are likewise of use, from one-half of an inch bore to a fine capillary.

Opake objects may be preserv'd in a box divided into cells, each containing a few slips of card, &c. on which the objects are glued with strong gum water, or mouth glue; and if these little slips are stained with several colours, which may give a contrast to that of the object, it will be seen to the best advantage.

All other sorts of little crawling animals, which are so very small that one can hardly touch them without destroying their lives, are best glued as it were upon the point of a fine sewing needle, first dipped in turpentine. (The needle being first made fast to the end of a short bit of stick by way of handle to it.) If you do but just touch the back or side of any one of these minute animals therewith, it will stick so fast thereto, as not to be able to remove itself; by which means they may be examined with ease and pleasure. The sewing needle must be held between the nippers, and so placed before the magnifier, that any part of the animal may be turn'd before the microscopical lens, by twisting the handle of the sewing needle, as you find occasion.

Hairs, wings of flies, small feathers of birds, &c. are best perceived, and easiest examined, when placed between two muscovy tales in an ivory slider.

A me-

A method of measuring objects that are viewed in compound microscopes.

THE general practice being formed under the consideration, that a person of a common sight sees objects distinct at about eight or ten inches distance from his eye, let us suppose ten inches; if the same person looks upon the same object with a lens of one and a-quarter inch focus, he will see this object eight inches nearer to his eye; and as the angle formed by the image on the retina, appears eight times greater, so knowing the focus of any small lens, it will be easy to find how much the appearance of the object is magnified, by finding how many times its focus is contained in eight or ten inches, &c. but as this method is doubtful in several respects, we shall only mention the difficulty of coming at the precise focus of a very small lens; and also observe, that those who are short-sighted, cannot comply with a base of eight or ten inches for their calculations; and thence proceed to the following easier method.

All convex lenses of any focus, have the property of doubling the apparent diameter of an object, and consequently of quadrupling the surface, * provided the object is at the focus of the glass on one side, and the eye in the opposite focus on the other side.

Take a double convex lens of eight or six inches focus, fig. 21. and fix it at A, perpendicular to a rule FG, divided into inches and parts upon a sliding piece at B; stick a piece of white paper as at D, two or three tenths of an inch broad, and three inches long, on which draw three black lines which shall divide the breadth into four equal parts, and observe that the middle

* Journal Œconomique pour le Mois d'Aout, 1753.

the center of this paper corresponds to the center of the lens; an eye-piece E must also slide upon the rule. Being thus prepared, go into the darkest and most remote part of a room from the window, and direct the glass A towards any remarkable object without doors, and move the sliding piece B, until the focus is determined upon by the rule, by a distinct representation of the object; count the inches and parts between the edge of the slider B, and center of the lens at A, and slide the sight E on the other side of the lens to the same distance, this will give the double focus.

Place one eye close to the sight at e, and with the other eye look at the object D; you will then find the image seen through the glass A, and expressed by the dotted lines, to be double the breadth of the same image seen at the same time by natural vision; this holds good whatsoever the focus of the lens may be with which you make the experiments: the same proportionable distance being attended to between the eye and the lens, and from thence to the object, the breadth of the object will always be double to that seen by the naked eye.

In fig. 22. Let the angle AFB, be equal to that made by the naked eye without a glass, from the rays of light, passing by the extremities of the object till they unite in the eye at the point F.

The angle DFE, is equal to that which first came parallel from the sides of the object AB, to IK, from whence they were refracted through the lens to the point F its focus.

CO, is equal to the focal distance of the lens on the side next the object; cF equal thereto on the side next the eye FO, the distance between the eye and the object.

It is evident the naked eye would see the object from the point C, of double the size it would appear if viewed from the point F; as the distance FO, is twice that of CO,

CO, we must prove the angle ACB, to be equal to that of IFK.

The optical axis FO, being perpendicular to the glass and surface of the object, the parallel rays AI, BK, flowing from the points A and B in their progression towards the eye, are also perpendicular thereto, until they arrive at the lens, where they project the diameter of the object at IK: hence $FC=CO$ and $IK=AB$, the two triangles ACB, IFK, will be similar, and thence the two angles at the points C and F, equal; but the visual rays FI, FK, continued to the surface of the object DE, will form the angle DFE, equal to the first angle ABC; therefore, as $CO:AB::FO:DE$, whence it is plain, that the diameter of the object, appears double the size when seen through the lens, than when it is viewed with the naked eye, and consequently quadruple in surface.

No notice has been taken of the double bending of the rays in their passage through the lens, it being a natural effect, has no weight in the demonstration, as appears from the line SS, which is in the direction of the passage of the rays through the lens, whence it may be supposed the rays bend only on the line GH.

On the removal of the eye from F to M, half the focal distance, the apparent diameter of the object will only be magnified one third.

On the contrary, if the eye be removed from F to N, double the focal distance; the diameter of the object will appear tripple: whence it is plain, that if the point of sight be taken at any other distance, but the focal point of the lens, the apparent magnitude will be either greater or less.

The simplest method to find the magnifying power of any compound microscope, is to have a little ebony rule, three or four tenths of an inch broad, about one tenth thick, and seven inches long; at each inch is fixed a piece

piece of ivory, about 2-10ths broad, the first inch being intirely ivory, is subdivided into 10 equal parts. See fig. 23.

A piece of glass, fixed in a brass or ivory slider, on which is drawn two parallel lines, across its diameter, about 3-10ths of an inch long; each tenth being divided, viz. one into three, the second into four, and the third into five parts: this is called a micrometer. See fig. 24.

The use of these are as follow; place the micrometer fig. 24. on the middle of the stage, and the rule fig. 23. on one side, but parallel to it; then look into the microscope with one eye, keeping the other open, observe how many parts, one tenth of a line in the microscope takes in upon the parts of the rule seen by the naked eye. For example, suppose with a fourth magnifier, that 1-10th of an inch magnified, answers in length to forty tenths or parts on the rule when seen by the naked eye; which shews that this magnifier increases the diameter of the object forty times.

The simplicity of this method, gives general satisfaction to those who can manage it; but there are some people who find it difficult, from their not having been accustomed to observe with both eyes open, for such persons another micrometer is provided.

A micrometer for a compound microscope.

FIG. 28. represents this micrometer; it is applicable to the body of any compound microscope. It was made for his majesty in the year, 1761, and with it was then presented a manuscript of its use, of which the following is an extract with some alterations.

The screw has fifty threads to an inch, it carries an index, pointing to the divisions on a circular plate, fixed

c

at

at right angles to the axis of the screw; its revolutions being counted on a scale of one inch, divided into fifty parts.

Thus every revolution of the micrometer screw, determines 1-50th part of an inch, and the circumference of the circular plate, to which the index of this screw points, being divided into twenty equal parts, we have by inspection any certain number of these parts contained in any part of one single revolution of the micrometer screw: by this means we obtain one single thousandth part of an inch.

To the sliding piece of this micrometer, is fixed a small needle in such a manner, that its point may traverse across the field of view, by which means we are enabled to measure the length and breadth of the image of any object applied to the microscope, but not that of the object itself, without another assistance.

This requires an attentive eye to watch the motion of the needle's point, as it passes over the image of a known part of an inch placed on the stage; we acquire a very small part of an inch by help of the following scale. Fig. 25, 26, 27. in which the two lines ca , cb , with the side ab , form an isocelles triangle; ca , and cb , being each of them two inches long, and the short side ab , exactly 1-10th of an inch. The two long sides ac , bc , may be of any length we please, and the short side equal in length to 1-10th of an inch; the longer sides may be said to represent the lines of lines, upon a sector opened to 1-10th of an inch: hence whatever number of equal parts ca , cb , are divided into, their transverse measure will be such a part of 1-10th of an inch as their divisions express. Thus if it be divided into ten equal parts, this will divide the inch into one hundred equal parts, the first division next c , will be $=$ 1-100th part of an inch, because it is the tenth part of 1-10th of an inch. If these lines are divided into twenty equal parts,

parts, the inch will by that means be subdivided into two hundred equal parts. Lastly, if *a b*, *ca*, are made about three inches long, and divided into one hundred equal parts, we obtain a division of 1-1000th part of an inch, as in fig. 27. In this figure the breadth *a b* is 1-10th of an inch, the next division to it is 99-100th parts of 1-10th; or in other words, it is 1-1000th part of an inch shorter than 1-10th, and so on till you come to the point *c*.

The first of these scales was drawn on a silver bar, in form of fig. 25.

This scale has been since changed by Mr. Cummins, thus; instead of making a solid bar in the shape of fig. 25. he made a perforation of the same shape, between the edges of two plates, as in fig. 27. which is more agreeable to the eye, when viewed in the microscope, the light passing thro' the aperture; and in the body of the microscope to be used with this apparatus. At the field of view was placed a circle of 1-6th of an inch diameter, cut on a glass plane, which is to be clipped by the inner edges of the sectoral scale, in order to come at the magnifying power of the instrument.

But this apparatus, as hitherto applied, is not so useful as the following; therefore we shall proceed to give,

The use of the micrometer and sectoral scale, when drawn on glass or muscovy talc.

FIG. 28. represents the micrometer which we mentioned before; to place it upon the body of the microscope, open the circular part *F K H*, by taking out the screw *g*, and throwing back the semicircle *F K* which turns upon a joint at *K*, as may be seen in fig. 28. Now turn the upper tube of the body of the microscope, so that the small holes in both of them may coincide to

let the needle *g* of the micrometer have a free passage through them, and screw it fast upon the body by the screw *G*, passing through the two ears *F* and *H*, and it will then appear as at *X*, fig. 1. Place the sectoral scale, fig. 26, which is drawn on glass, on the stage, and adjust the microscope to its proper focus, or distance from the scale, which slide on the stage until the largest extremity appear in the middle of the field of view, and bring the needle point, by turning the head *L*, to touch one of the lines *c a*, exactly at the point answering to 20, the index at a fig. 28, being set to the first division, and that on the dial-plate, which could not be represented in this figure being set to No. 20, which is both the beginning and ending of its divisions. We shall then be prepared to find the magnifying powers of every magnifier in any compound microscope whatsoever, if the above cautions are attended too.

EXAMPLE.

Every thing being prepared as we have directed, and any magnifier, suppose No. 4, in the first table to be used, turn the micrometer screw until the point of the needle has past over the magnified image of the 10th part of one inch, then the divisions where the two indices remain, will shew how many revolutions and parts of a revolution the screw has made, while the needle-point traversed that magnified image of 1-10th of an inch, the result was twenty-six revolutions of the screw, and fourteen parts of another revolution, which is equal to $26 \times 20 + 14 = 534$ thousandth parts of an inch.

Hence we derive an easy way to count the divisions on the micrometer, thus finding upon the straight scale twenty-six divisions while the needle point passed over the magnified image of 1-10th part of an inch, which being multiplied by 20, because the circular-plate *C D*. Fig. 28, is divided into twenty equal parts produces 520, then

Fig. 24

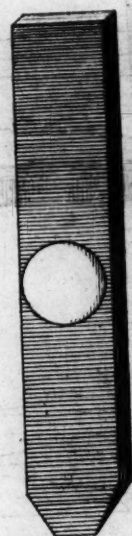


Fig. 21

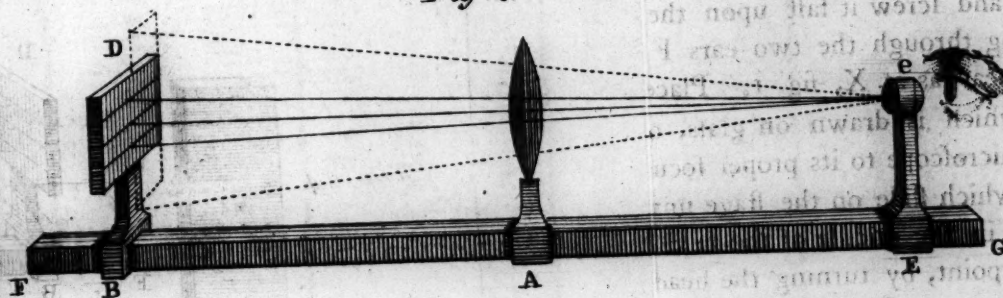


Fig. 22

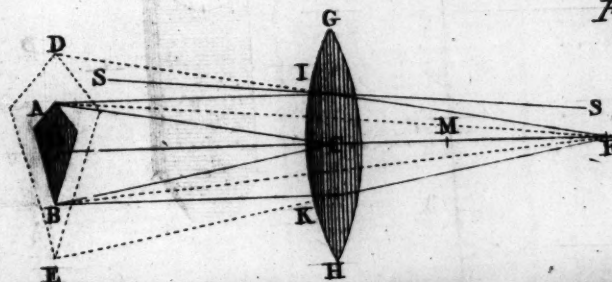


Fig. 23



Fig. 26



Fig. 25



Fig. 27

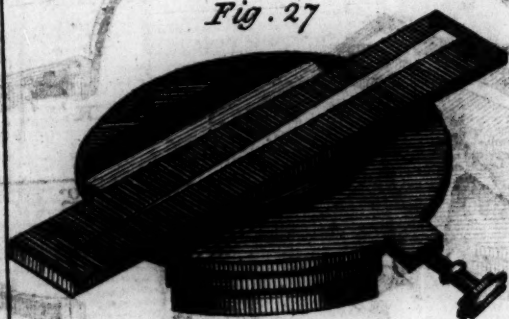
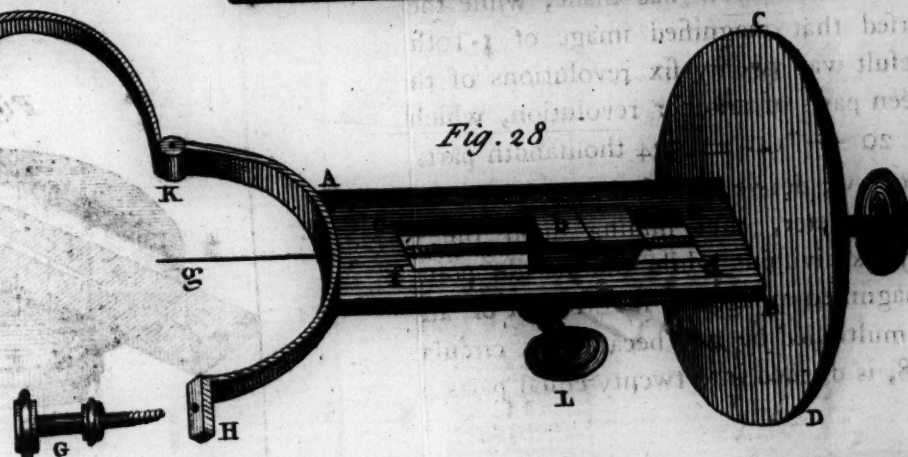


Fig. 28



then adding the fourteen parts of the next revolution we obtain the 534 thousandth parts of an inch, which is the measure of the image of 1-10th of an inch magnified at the aperture of the compound microscope, or rather the field of view to be equal to the measure of 5-10ths and 34-100redths parts of another tenth.

And as we suppose the compound focus of the two eye-glasses in the variable microscope to be one inch 2-10ths, = 1,20, its double will be equal to 240 thousandth parts of an inch for the distance of the eye from the image, or from the needle-point of the micrometer. — Again, if we take the distance of the image, from the object on the stage which is 6, 40-100 inches equal to 6, 40 thousandth parts of an inch, and add thereto 240, double distance of the focus of the eye-glass, we shall have 880 thousandth parts of an inch for the distance of the eye from the object, and from the property of the eye-glass in doubling the image, we must also double the number 534, found upon the micrometer which makes 1068, then by the following analogy, say;

As 240, the distance of the eye from the image, is to 880, the distance from the eye to the object :: so is 1068, the double of the measure found on the micrometer, to 39,16 the number of times the microscope magnifies the diameter of the object.

Having thus obtained the magnifying power of all the magnifiers when applied to the compound microscope, by shewing how much the object is magnified; the next step to be considered is to calculate a table of the powers of every single object lens, of the particular microscope the reader may be possessed of, because it is almost impossible to work two deep magnifiers, that shall be precisely of the same focus; therefore the table I have here subjoined, will not answer every microscope, but may nearly answer the variable microscopes which I make.

The

The above analogy will answer to every compound microscope, but the result will not be the same.

The next enquiry is the minuteness of the object itself, which requires a table shewing the apparent size of objects seen under the various revolutions and parts of a revolution of the micrometer screw; to perform this,

Put on any magnifier, as No. 4, and the sectoral glass-scale on the stage, raise or depress the microscope till the object appears distinct, measure the distance from the stage, to the hole, thro' which the needle enters the body of the microscope, then apply the micrometer, and adjust the point of the needle to the edge of the field of view, count how many whole revolutions the micrometer-screw makes in passing across the diameter, which we find to be 40, now multiply 40 by 20, (the number of parts the dial-plate is divided into), and we shall obtain its measure to be equal to 800 thousandth parts of an inch, its double is equal to 1600.

The measure of the distance from the stage to the needle-point, as found above, being equal to 640, to which adding the double focus of the eye-glass = 240, we obtain 880 parts for the distance of the eye from the object, then doubling the number found on the micrometer, which is 1600; say,

As the distance of the eye from the image 240: is to double the measure of the field of view 1600 :: so is the mean distance of the eye from the object 880: to a fourth number 586,666, which divided by 40, the No. of revolutions of the micrometer-screw, produces 146.666 thousandths parts of an inch. The two tables follow:

TABLE I.

TABLE I.

TABLE II.

Revolutions.	The measure of any number of revolutions given to any extent on the stage.
1	146
2	293
3	440
4	586
5	733
6	880
7	1026
8	1173
9	1320
10	1466
20	2933
30	4400
40	5866

MAGNIFYING POWERS.			
	Diameter	Surface.	Solidity.
1	624.85	389376	241970324
2	184.36	32856	6035504
3	69.51	4716	328509
4	39.16	1521	59319
5	26.46	679	17576
6	16.71	256	4096
1	203.25	41209	8365427
2	79.89	6241	493069
3	45.65	1025	46125
4	28.35	784	21952
5	15.92	225	3375
6	12.39	144	1728

The first of these tables was made from the mean distance of all the magnifiers from the stage, or in other words the mean height of the needle-point from the object; but as this is done only to shew how to form such another sett of tables, if more exactness be required, it may be necessary to have three such tables, at least one for the mean height between the two greatest, one a mean between the two middle magnifiers, and a third between the two shallowest.

These tables being once made, their use is very easy; the first table of the measures answering to the revolutions

tions of the micrometer-screw, being expressed in the thousandth parts of an inch, are easily read as follows. Opposite to 20 revolutions, you find the No. 2933, the first fig. 2, is 2 inches, the second being 9, shews 9-tenths, and the two last figures being 33, are 33 parts of 100, which we have divided each single 10th of an inch into, by means of the micrometer-screw; therefore the measure of 20 revolutions, is equal to 2 inches 2-tenths, and $\frac{33}{100}$ dreth parts of another tenth.

Again, if you measure nine revolutions by the micrometer-screw in the same manner, it will be found from the first table to be 1320, which is equal to one inch, three tenths, and twenty parts of 100 of another tenth.

Likewise in the same table 1, where we have but three figures as at five revolutions, which are 733, here the first is seven tenths of an inch, and the two last 33 parts in 100, of another tenth, that is seven tenths and $\frac{33}{100}$ dredth parts, and so of the rest.

In the column entitled Diameter in the second table, the numbers are also expressed in thousandth parts of an inch, so that the two last figures to the right-hand are decimal parts of one tenth of an inch; the third figures from the same hand are tenths, and all the rest are whole inches. As all these measures are computed from the number of revolutions of the micrometer-screw, in passing over the magnified image of 1-10th of an inch; it is plain, that the numbers in this column which stand against the number of each magnifier, express the true measure of the magnified image.

EXAMPLE.

Against the third magnifier which is set in a button, we find 6951, this shews that one single tenth part of an

an inch is magnified to the length of six inches, 9-10ths, and 51-100th parts of another tenth in length, — we therefore without exaggeration say, every object examined with this magnifier, is magnified sixty-nine times and half, and so of all the rest.

The use of the preceeding Tables.

IF the apparent length or breadth of any object be required, measure it by turning the micrometer-screw, until the point of the needle has passed over that part of the image under consideration, and you obtain the revolutions agreeable thereto.

EXAMPLE I.

Suppose you have 20 revolutions, which in the first table answers to 2933, this is equal to 2 inches 9-10ths $\frac{3}{10}$ breadths; then to find the size of the object itself, enter the second table with the number of the magnifier in use; suppose the third magnifier, against which in the column entitled DIAMETER, you will find 69.51, which shews the third number magnifies 69 one half times; this shews the diameter of the object to be no more than 1-69th part of two inches and 9-10ths, — whence dividing the number in the first table by the magnifying power found against the number of the magnifier in the second, the true length of the object itself is found to be 42-100th parts of 1-10th of an inch.

If any number of revolutions of the micrometer-screw should happen between 10 and 20, 20 and 30, &c. the measure must be taken out from the first table twice, as follows :

f

Supposè

Suppose you have 25 revolutions, take out the numbers answering to 10 and 5, add them together, and you obtain your desire; or thus,

Revol.				
20	--	1466		
5	--	733		
Revol. -- 25	--	2199	its Measure	= 2 -- 1 $\frac{33}{100}$ ths.

EXAMPLE II.

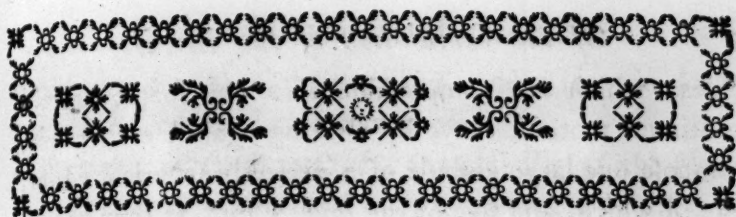
Suppose we have 25 revolutions of the micrometer-screw, they will be found equal to 2199, (as we have shewn above), which is 2 inches 1-10ths and 99-100 parts of another tenth, and if we apply the first magnifier, which is sett in what is generally called a button, in the second table against the first number 1, will be found 624.85, we reject the fractional parts, to prevent exaggeration, which shews that number 1, does at least increase the image of the diameter of any object viewed through it 624 times. Therefore the object under consideration is no longer than 1-624th part of 2 inches 1-10th, and 99-100 parts of another tenth, which by the preceeding method of calculation will be equal to 35-100dredth parts of 1-10th of an inch,

EXAMPLE III.

If we had only two revolutions, which in the first table answer to 293, this number expresses as we have before shewn, 2-10ths and 93-100th parts of another tenth, the same first magnifier being applied to the microscope.— The diameter of such an object would be no more than the 624th part of 2-10ths $\frac{93}{100}$ dredth parts of another tenth, which is equal to $\frac{293}{10000}$ thousandths parts of

of one single tenth part of an inch. What an amazing minuteness? and if we reflect on the far more surprizing minuteness of living animalcula, which are extended throughout the creation to a measure extremely smaller than that above-mentioned, and all discernable by a human eye, assisted with such magnifying powers, how can we forbear exclaiming with the Psalmist, O Lord, how wonderful are all thy works! in wisdom thou hast made them all!





A
NATURAL HISTORY
Of a great VARIETY of
AERIAL, TERRESTRIAL, and AQUATIC
ANIMALS, &c.
CONSIDERED AS
MICROSCOPIC OBJECTS.

Of the circulation of the blood, and how to
examine it by the microscope.

 HIS noble fluid, the blood, yields us the most
sublime speculations imaginable, by the assist-
ance of the microscope. For by the help of
it, human blood, and that of land animals, is
found to consist of round red globules, which float in a
transparent fluid, each of which is compos'd of six smal-
ler, and more transparent ones, and each of these (as
Mr. Leeuwenhoek has shewn in his 128th epistle to the
Royal Society) into six more minute and without colour.
He hath also shewn us, how easily six soft flexible glo-
B bules,

2 *Of the Circulation of the Blood.*

bules, which are compressible into any shape, and in continual motion, may, by striking against each other, compose one large globule of a perfectly spherical figure, one of which, and five of the smaller sort, as they appear in contact, the sixth lying behind, is represented fig. 29. which, by their mutual attraction to, and pressure against each other, readily unite to form a perfectly round body, as at fig. 30. Their attraction towards each other is so considerable, as to form a kind of fleshy substance, when brought into contact; and their specific ^a gravity more than the serum in which they float.

How these globules, and also the more minute ones of which they are composed, are occasionally separated, in order to pass through extremely minute vessels, which without such a separation they cannot possibly enter, and how they re-unite again in vessels where they have more room, is easily comprehended by a due consideration of the two foregoing figures.

The diameter of a common round globule of human blood, is equal to the 1940th part of an inch.

In order to view the blood with the microscope, upon the tip of an hair pencil, take a small drop of warm blood, immediately as it comes from the vein, and spread it as thin as possible upon the object-carrying glass of the microscope, and apply it between the object plate and springs, to the first and second magnifiers. It may also be extremely well examined, if a little of it be taken up into a small, but very thin capillary tube, which being held in the nippers of the apparatus, may be readily applied to the magnifier. If you dilute a drop of blood with warm water, and apply it either of these ways to the magnifier, some of the larger globules will be separated from each other,

^a Phil. Trans. No. 361.

other, and several of them will be divided into the smaller ones of which they are composed.

By either of these methods, the globules of the blood may be distinctly seen, and a little practice will discover any alteration that may happen in the colour, shape, or size of them; in its several changes between sickness and health. Mixtures of medicinal, or poisonous liquors, may be blended with it immediately as it comes from the vein, and a drop of this mixture, if applied as before directed to the microscope, will discover what alterations can be produced on the contexture of the blood. The vessel in which the blood is received, should be put into a basin of water, somewhat hotter than the blood ^b, to prevent its coagulating before the mixture.

The circulation of the blood through its vessels, is to be seen in such small creatures, whose transparency permits us to look within them, or in the thinnest parts of larger ones; by which we are very well informed, the whole animal system being established on the same plan, the circulations carried on in vessels of a like form, both in the meanest and noblest living creature, and accelerated or retarded by the same causes.

In these small creatures we are not only able to see the general course of the blood, but can perfectly distinguish each globule, and the alteration they suffer in passing out of the larger into the more minute vessels, many of them being so small, that single globules can scarce enter, till they are compressed into an oval form; and yet these very vessels are large, when compared with the finest of all, in which the globules must be divided

B 2

and

^b The exact blood-heat of the water, may be obtained by a pocket thermometer, made with quicksilver, with which the reader may be supplied at my shop, at Tycho Brahe's Head in Fleet-Street, No. 60.

4 *Of the Circulation of the Blood.*

and subdivided into their smallest component parts, before they can find a passage.

Providence has been surprisngly careful in the disposition of the veins and arteries, for these last, which convey the blood to the extremities of the animal, continually lessen their diameters in their progression, and divide into smaller branches. At which division, the globules rush against an angle, which as it were causes them to recoil upon those immediately behind, before they can readily separate into the two smaller branches C D, of the artery A B, fig. 31. in which the blood flows upwards from B to A, towards the extremity; and on the contrary in its return back from the extremities to the heart, their diameters increase, and those smaller vessels are continually uniting into larger, as in the foregoing, fig. 31. the branches C and D join their currents in the vein E F, till at last all their streams fall into one, at every such conjunction of two branches, as at E, and their streams violently rush against each other, by which means unnatural cohesions are prevented.

The microscope affords us an ample view of the veins and arteries, the latter of which is very distinguishable by a protrusion of the blood, at each contraction of the heart, then a stop, and then a new protrusion, continually succeeding each other, whilst in the veins it rolls on with inexpressible rapidity.

The ingenious Mr. Leeuwenhoek hath told us, that with great admiration he saw in the utmost extremities of a very small fish's tail, how the larger arteries were divided into the finest vessels ^c, and many of the small veins, which returned from the said extremities, met together in a larger vein; that there was such an agitation of that blood, which flowed from the larger arteries,

towards

^c Arc. Nat. tom. iv. p. 167.

towards the evanescent ones, at the extremity of the tail, and returned afterwards through many minute veins into a larger one, as can hardly be conceived. In the larger arteries he saw a continual new protrusion of the blood's course, received from the heart; but in the smaller, the motion seemed equable without any such repeated propulsion; and though no colour appeared in the minute vessels, yet in the larger arteries and veins, that were near the extremity of the tail, the blood was plainly red.

The exact magnitude this fish appeared of to the naked eyes, as delineated by him, is represented in fig. 32. Its tail magnified, as it appeared in the microscope, at fig. 33. in which were seventeen little bones or gristles, that give a stiffness to the tail, three of them are shewn by the letters A B C, on each side of which he saw a very open communication of the veins and arteries, the blood running through arteries, and returning back through veins, which were of the same size, and evidently a continuation of the same vessel; this was distinctly seen in 34 different places, so that in the tail of this small fish could plainly be seen 64 blood vessels, 34 of them arteries, and as many veins, besides the little spaces about D and E, which were not observed.

This will be better understood by a microscopical representation of part of one of these little gristles F H G, fig. 34. on each side of which runs an artery I K and M N. The blood flowing rapidly from I and M, to K and N, their open communication with the veins K L, and N O, from whence it returned to L and O, so that both these were but one continued blood vessel; for no vessel can be properly called an artery beyond the pulsation; farther than which, and returning towards the heart, it may be called a vein; for veins, as by the pre-

sent figure appears, are only arteries elongated; and as they generally divide into branches that escape the sight, it is very difficult to determine where the arteries end, or where the veins begin. If in the tail of this small fish, the whole bulk of which was no bigger than that of fig. 32. and consequently under half an inch in length, 34 distinct circulations of the blood could be seen, how incredibly numerous must that of the circulation be in an human body? nor is it to be wondered at, when we see it issue forth at every prick of a pin or needle. In this consideration he also adds, that he is fully convinced in a space no bigger than his fore finger nail, a thousand distinct circulations of the blood are performed.

Mr. Leeuwenhoek observed the motion of the blood in a small vessel, in the tail of a tadpole, somewhat wider than to admit a red globule thereof, as A and B, fig. 35. which vessel is called an artery, through which the blood coming from the heart, in the direction AB, is impelled with great swiftness, and divided at B into two branches, BC and BE, which are again united at D, and continue so to F, where they are again divided into two other branches FG and FI running crooked till they are again united at H, where they formed a somewhat larger vessel as HK, and became bigger at K, for which reason we must call the blood vessels ABC, DFG, and ABEFI, arteries^d, because they convey the blood to their greatest distance from the heart at G and I, and the blood vessels GHK, and IHK, veins, because they return the blood to the heart again.

In another place he saw the blood running in an artery, large enough to admit about 20 red globules^e at once; this was a great artery in proportion to that before-

^d Arc. Nat. Epist. 119. ^e Phil. Transf. No. 260.

fore-mentioned, a small part of which is delineated at L M, fig. 36. out of which proceeded a lesser, as M O. The blood in the vessel from L to M, had not so quick a motion as it had in others, because the blood in the vessel at R, did in a manner stagnate, inso-much, that no separated parts could be distinctly seen, it appearing there of one uniform red colour; yet in the vessel M O, the circulation was as swift as in any other vessel. That the blue spots, occasioned by a fall or bruise, is not stagnated blood, which perspires before it begins to corrupt through the skin with the sweat, Mr. Leeuwenhoek was convinced of by the following observation. The blood at R being thus without the least motion, it was by every pulsation of the heart impelled upward, from N to P, and the next moment recoiled back again, and this alternately with an undulatory motion; as is known if never so much violence be used in pressing water, yet it cannot be pressed closer than it was before; so the blood being now impelled forwards thro' the heart, cannot be compressed into a less space; this being so, we must conclude, that the tunic of the blood vessels between N and P, and also somewhat below N, is distended at every pulsation of the heart; and as soon as this uncommon distention is performed, so soon also does the tunic of the vessel contract itself again; whereby the blood, that was thus pushed forwards, is forced to run back again. After a short space of time he saw the blood begin to move from P to R, in such a manner as to be pushed back again, and that during his observation, the blood vessel M O, was a little more extended; consequently more blood ran through it than when he first began to look upon it; the blood in the vessel N S, wherein was little or no motion before, now ran as swift as in any other vessel; the vessel P Q was so small, that

only one single globule could pass through it at once, wherein not the least motion, at his first observing it, could be discovered, now began to flow; yet the particles of blood, which at first passed through it, were but few in number, and consequently far asunder; henceforward all the blood from P to R was put into motion, as well by being pushed forward, as by recoiling back again, and that at every pulsation of the heart. Mr. Leeuwenhoek spent about two minutes in these observations; from whence it plainly appears, that the stagnant blood cannot only be made to move again by the motion of the heart, which we call the beating of the pulse, but also that the coagulated red globules are again dissolved, and assume their first figure; from which we may reasonably conclude, that the coagulated blood in any animal, occasioned by a blow or bruise, can in a few days be made to move again; it being taken for granted, that the heart of a man pushes out the blood seventy-five times in one minute, which is 4500 in one hour, and 108000 times in the space of a day and night; and finding that in 10 days time the coagulated blood seemed to vanish, and also considering that in this time the heart performs 1080000 pulsations, and that in each motion, into several vessels together, there has been loosened and set a-going the quantity of a grain of sand, how much more will be pushed forward in the same time? Mr. Leeuwenhoek could see the blood received from the heart at each impulse, in the vessel above-mentioned. If we suppose that the quantity of a cubic inch of coagulated blood, occasioned by a blow, is too much, and that seldom so much is coagulated at once, we may easily conceive, that such coagulated blood, by means of so many protrusions as above-mentioned, may be loosened, and its motion again restored, if not in all, yet in most of the vessels.

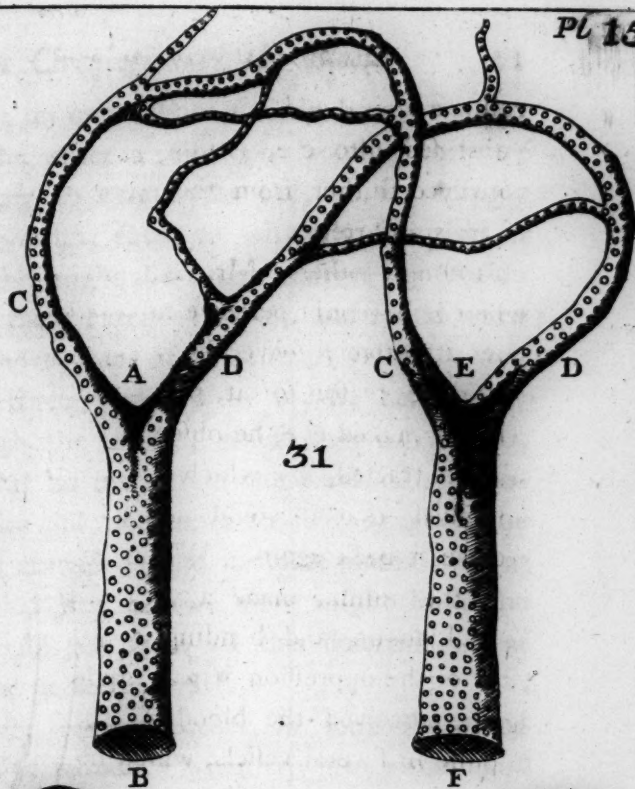
At

At another time Mr. Leeuwenhoek laid one of these tadpoles upon a piece of white paper, a little while before he came to look upon it. A small part of the tail was wounded by the skin sticking to the paper; so that out of an artery in the excoriated part, so large that about four red globules of the blood might pass through it at once, there flowed some blood that remained without motion about the wounded part, yet that whereon his eye was fixed, not being half a hair's breadth from the excoriated artery, there proceeded a branch of a vein, wherein the circulation of the blood did still remain, as if the artery had not been broken, fig. 37. T V, exhibits the artery wounded a little above V. V X shews the extravasated blood. V W, the small artery wherein the blood retain'd its full course, although it was so near the artery T V, out of which the blood flowed; which at first seemed very strange, but observing that the blood-vessel V W was united at W to a large blood-vessel, that conveyed the blood to the heart, the blood out of V W was continued as swift as if it had been impelled from T to V, in such a manner that Mr. Leeuwenhoek imagined, the vein at V had not been united with T, but had lain with its aperture at V, in the extravasated blood; so that the extravasated blood was only for a little sucked up and conveyed through it. He then saw a vein wherein the motion of the blood seemed very uncommon, as at fig. 38. whereof a b represents an artery, whereby the blood is impelled with great velocity from a to b, then b c, whereby the blood is conveyed towards the heart, must be called a vein, close by which lies another artery d c e, wherein the blood is conveyed from the heart from d to c; now if the vein b c be united with the artery d e, as is seen at c, and the blood be thus conveyed from c to e, b c should be called

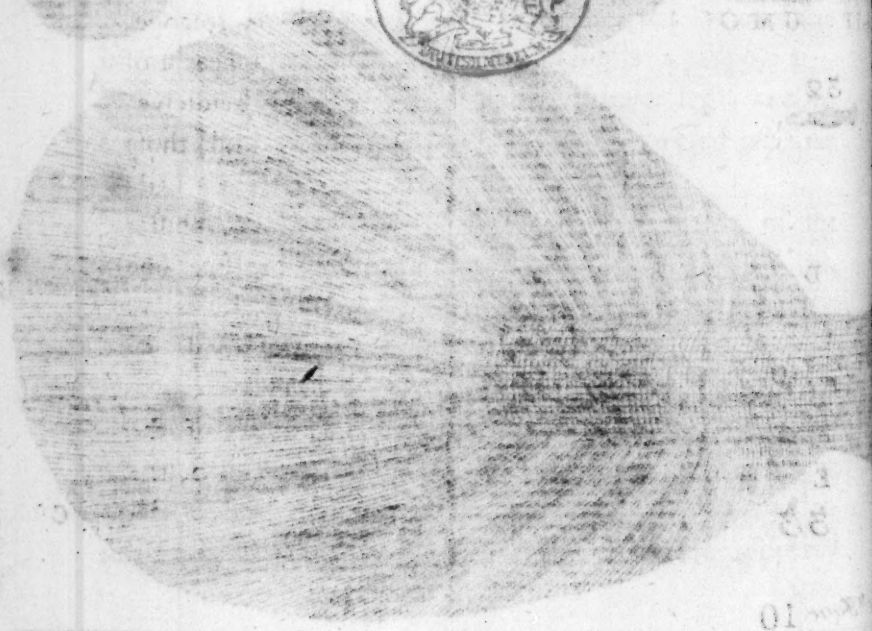
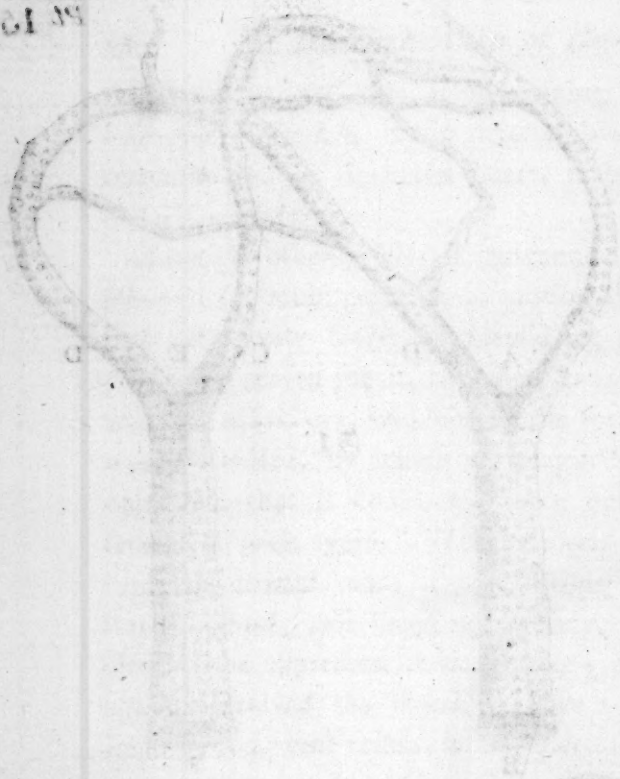
called a vein, and the blood coming to c, being there transfused into c e, is the arterial blood, because it is conveyed thither from the heart, it being certain that d c e is an artery.

Amongst others, Mr. Leeuwenhoek had a tadpole, wherein he could perceive no motion at all of the blood, how attentively soever he view'd it; at first there appear'd no reason for it, till upon examining this animal with his naked eye, he observed the fore part of his body was contracted, by which he imagin'd the heart was so oppress'd, that it could not force out the blood, and receive it back again. Whilst he was thus contemplating, the animal made a very strong motion; beating its tail about, and bending its body, by which it got clear of the oppression it was under; and on viewing it again, perceived the blood to have a slow motion, and impulse in several vessels, which increased till it at length came to its proper motion, yet not with such velocity as it would have had, if the heart or body had not been oppress'd. Mr. Leeuwenhoek says, that the motion of the blood in these tadpoles, exceeds what he ever saw in any other animal. Fig. 39. exhibits a tadpole arriv'd to such a bigness, as to use its hinder legs; and the fore legs were also discernable, but yet covered with the skin.

Mr. Leeuwenhoek observed the circulation of the blood in several butts, one of which, bating the tail, was but an inch in length; the greatest motion of the blood observable through the fins, was on each side the various little single bones placed therein, where the blood-vessels were so large, that 25 of those particles which constitute the blood of a red colour, could pass in breadth, but disappear'd as they drew nigh the extremity of the fins, small vessels being all along dispers'd from



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01 39

from the arteries; on one side of a little bone, runs an artery, and on the other a vein, corresponding thereto; and finding it easy to extend the tail, he accordingly stretched it in breadth, equal to what the fish gives in swimming, that he might the better observe the motion of the blood in these extended vessels, and found when the fish did not move, some of those small vessels, which before received three particles in breast, being now stretched out with the tail-fin, which they run a-cross, did not only admit no more than one particle, but likewise these particles did not move so fast, as when the vessels were not extended; and in some places were at such a distance, that one or two more might lie in the intervals, but could not from all this determine, that the particles were perfectly oval^f.

But to trace the matter further, he took the blood running from a live salmon, ^g when cut into pieces, and put it into a glass tube, no larger than a small quill, which in a short time congealed; but when it became partly fluid again, he put it into a smaller glass tube, and having placed it before his eye in the microscope, the particles being in motion, some of them appear'd of a flat oval figure, and others, which shewed themselves sideways to the eye, seem'd a little thick, and those whose sides did not directly face the eye, seem'd a little broader, without the least appearance of any globular form. Mr. Leeuwenhoek also put some of the same blood upon a very clean glass, and where the particles lay thin, he perceived them oval; nay in several ovals he discovered globules, and in some few fix globules.

Fig. 40. A B C D represent the oval particles of the blood of a salmon, that weighed 30 pounds; A B, the particles that appear'd flat and broad, but did not directly

^f *Arc. Nat. Epist.* 128.

^g *Phil. Transf.* 263.

rectly face the eye; those about c were streight before the eye, and for the most part a little clear sort of light in the middle, larger in some than others.

Mr. Leeuwenhoek, likewise, placed some of the blood of a very small butt before the microscope, which was not mixed with any liquor, only the particles lay in their serum, and are represented by fig. 41.

Those particles of the blood, which are distinguished by shining spots in the middle, are delineated fig. 42, Mr. Leeuwenhoek profocuted this enquiry yet farther, with a greater magnifier than he had hitherto used, and so he plainly made out the oval particles; now the greater the magnifying power of the glass, the swifter does the circulation of the blood appear; and having retarded this motion, he employed two or three seconds of time, in observing the little veins, and found, that in several small vessels, the oval particles were so broke, that he could neither see them, nor those, of which six constituted a particle of blood, but only a simple fluid of a faint colour, running along the vessels; but in a great artery at the tail, the blood mov'd so slowly, that he could easily discern the particles were oval; and not only so, but he likewise perceived more clearly than before, the globules that constituted the oval parts, if not always, yet at least for the most part, as represented in fig. 43.

How venous blood may become arterious without being first in the heart, appears by the following experiment. Suppose A B, in fig. 44, to be a vein, in which the blood view'd through the microscope, passes with great celerity from B to A; from this vein proceeds two small branches, C and D, which unite between E and F. Again suppose H I to be an artery, in which the blood moves upwards with equal swiftness from H

to I, out of H I arises a veinous spring, delineated in K F L; the blood moving from K to F, joins the other at F; and by this means, part of the blood coming from the artery, is thrown into the vein, as passing from F to G, and to the best of Mr. Leeuwenhoek's observation, a quantity of blood, just equal to that carried from K F to G, moves from C E to F, and directs its course upwards from F to L, so that whatever quantity of arterious blood passes through K F and F G, an equal quantity of veinous blood returns through C E and F L. Though the agreeable motion of the blood was formerly apparent, yet this experiment afforded him a very clear perception of the above-mention'd variety; and besides, this union of the blood-vessels was not formerly discover'd.

Mr. Leeuwenhoek, in his 112th epist. has given us an accurate delineation of the blood-vessels in part of the tail of an eel, whose whole length did not exceed that of the length of his little finger. The figure, as by him delineated, is represented in fig. 45. whereof A C E represents the veins, and B D F arteries.

The letter D represents an artery, from which a branch G proceeds, that is divided about H, into two lesser branches, one of them represented by the letters H I K; so much of this small vessel as reaches to I, is called an artery, because the blood may to that place be propelled in its progression from the heart. The other part I K of the same branch may be called a vein, because by it the blood is convey'd back again to the heart. In the other part of the same branch H L M, the blood is drove forwards till it arrives at M, where it is discharged into the vein E, which in this figure is the first place that can take the name of a vein.

Here

Here also it may be observed, that as the arteries are extended in length, they gradually lessen. And on the contrary, the veins increase in their diameters as they approach the heart.

Furthermore, from this same artery D, another vessel may be seen branching out from N, from whence the blood flows to O, and there discharges itself into the vein E.

Raise your eye a little higher to P, where another small artery advances from the great one D, towards Q, where it closes again with the vein E.

Also observe that about the letter R, another small vessel leads from the same artery towards S, at which place the blood that flows both from the artery D and B, is joined, and from thence pour'd into the vein C.

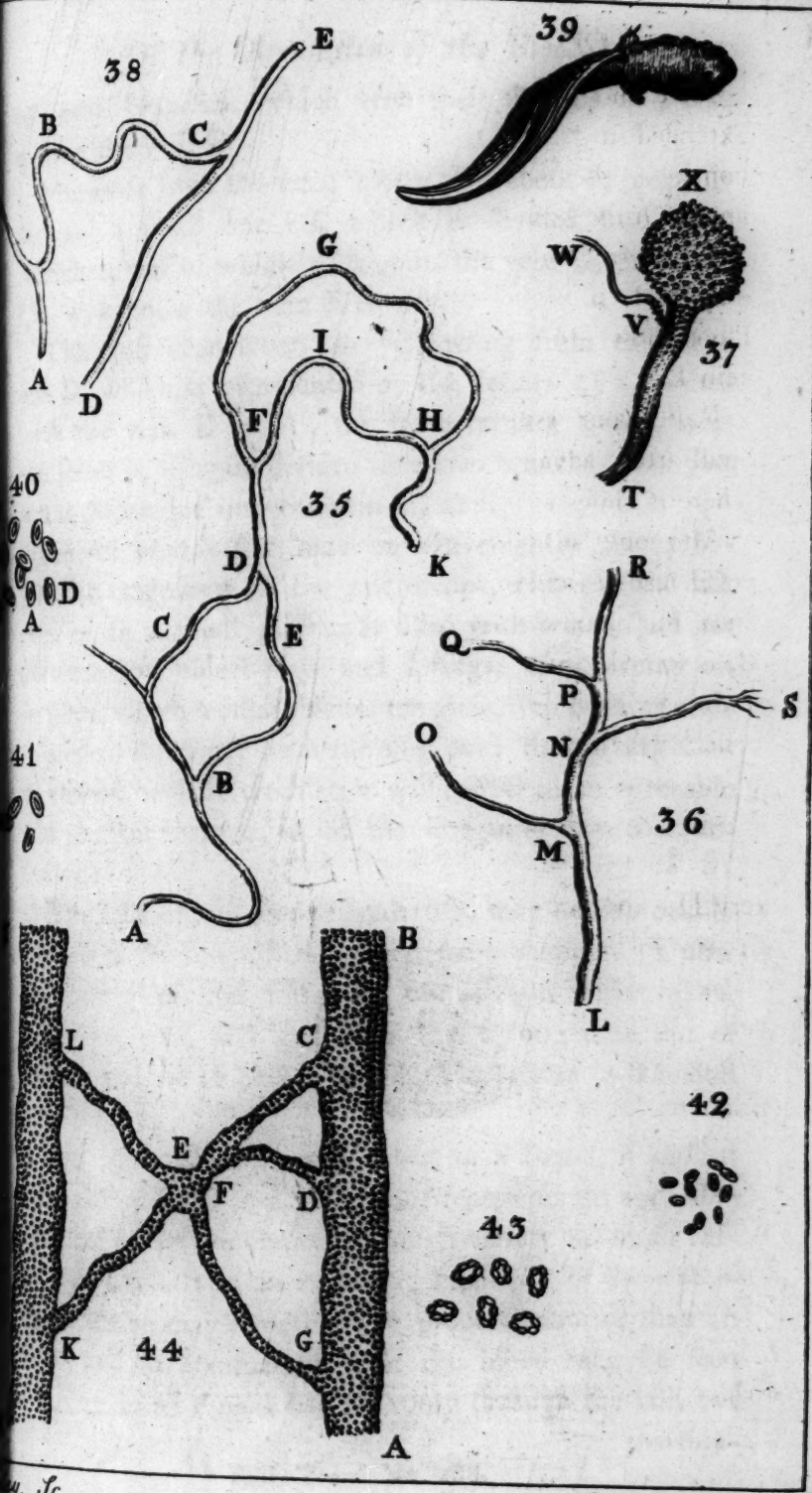
Somewhat higher, about T, advances a little blood-vessel, which is divided into two branches at V, so that from thence two distinct vessels may be seen to discharge themselves into the vein E, at X and h.

About the letter Y proceeds from the same artery D, another small vessel, which at Z branches out in two more minute vessels; the blood flowing through them towards a and b, where it is discharged into the vein C.

Not far from Y, about c, proceeds a small branch from the artery D, through which the blood also returns into the vein C, with which it joins at d.

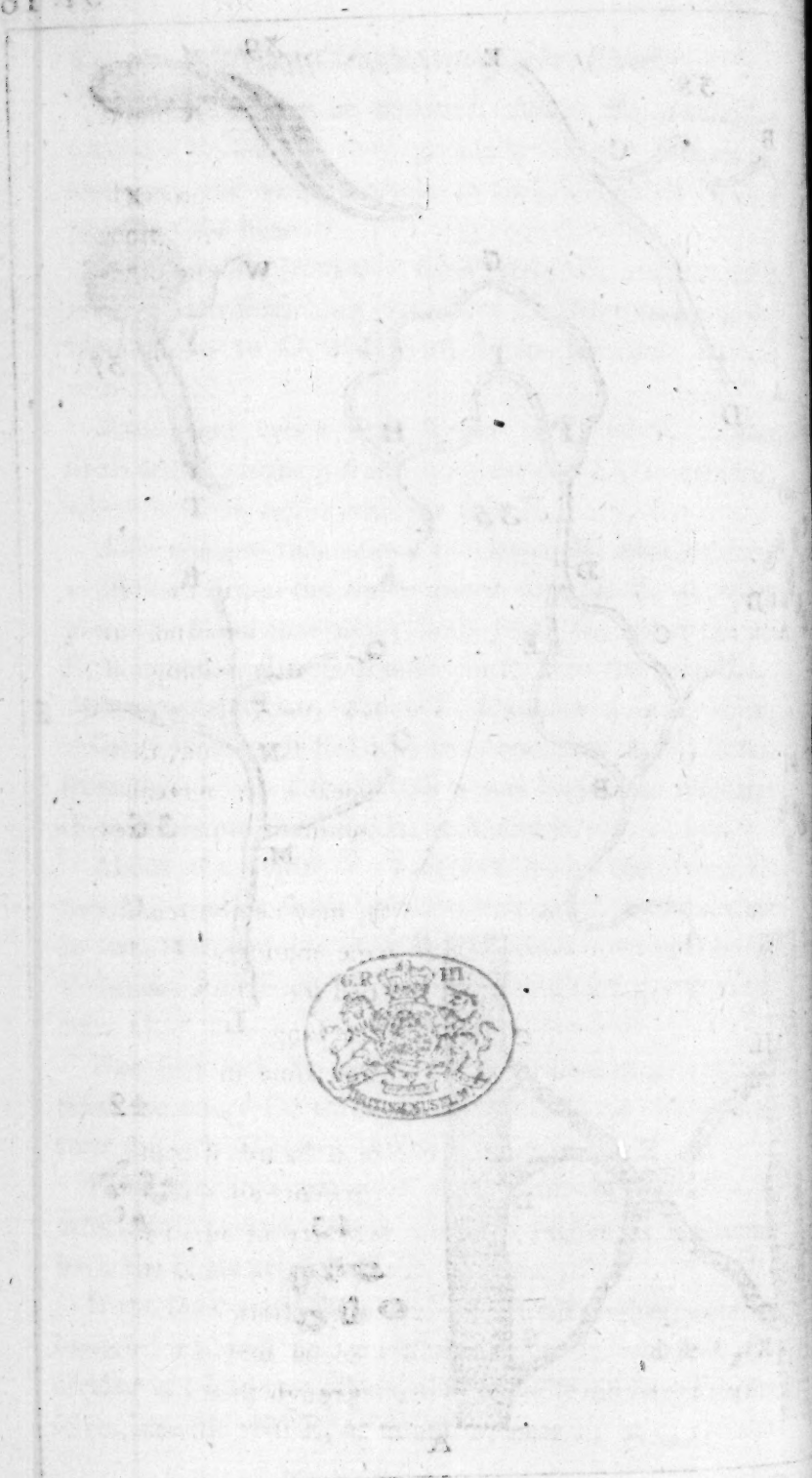
From the same artery D rises a minute branch e, f, which is separated into two lesser branches at f, sending back the blood to the vein E, at g and h.

If the same artery be examined a little higher, another branch I k l, will be seen issuing from I, which is also divided at l into two others, that likewise discharge themselves into the vein E, at m and n, near I; at o, are also



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two other branches, which vent their streams at p and q, into the vein C.

Moreover from the same artery D, about r, proceeds forward a small one r s, which is divided into finer branches, one of which r s t, joins the vein C, the other s, u, w, x, joins the vein E at x.

The most evanescent artery, flowing from the large one D, which is represented by the letters r y z, unites with the vein E at A; the same minute artery, near the letter u, is again divided into two branches, the part u b is discharged into the vein C, at t.

An eel of this size may be conveniently placed before the magnifiers in the microscope, either in the fish pan, or in a small glass tube filled with water, and put between the object-plate and springs, after wiping off its slime, which would obscure the glass, stop both its ends to prevent the water from running out; the tail may then be viewed, and the circulation will appear in an agreeable and pleasant manner, as in the foregoing figure is described.

The tails of any sort of small fish, may be also readily applied to the magnifiers in the same manner. Under the spring of the fish-pan, or tied on a flat glass, flounders, eels, and gudgeons live a long time out of water, and are to be had at almost any time in London alive.

Also the tail ^h of a water newt, or a lizard, if applied to the microscope in a glass tube, represents an agreeable prospect of the circulation, through variety of small vessels, particularly in an exceeding small one of the water-kind, which may sometimes be procured shorter than an inch, and so transparent, that the blood may be seen running in all directions, not only through the tail, but

particu-

particularly in every single toe, and through its fins or pointed branches. The blood may be seen running through an artery towards the extremity, and returning through a vein, with which its communication is very apparent, and surprisingly delightful.

Mr. Leeuwenhoek informs us, that he has observed the circulation of the blood, in the farthest joints of little crabs¹ hinder legs, with greater rapidity than in any other creature, and that their red globules were twenty-five times fewer than in any other land or water animal he had before examined.

Exceeding small crabs may be found under brickbats and stones, on the shores of the river Thames, when the tide is out.

The circulation of the blood may be seen in the legs and tails of shrimps, if view'd in water, wherein you have mixed a little salt; but in these the blood is not red.

I have frequently seen a fluid flowing through the filmy wings of grasshoppers, of a greenish colour.

The motion of the blood is also to be seen in the transparent legs and feet of small spiders, and in the legs of very small bugs, and an extraordinary vibration of the vessels not discernable in other creatures.

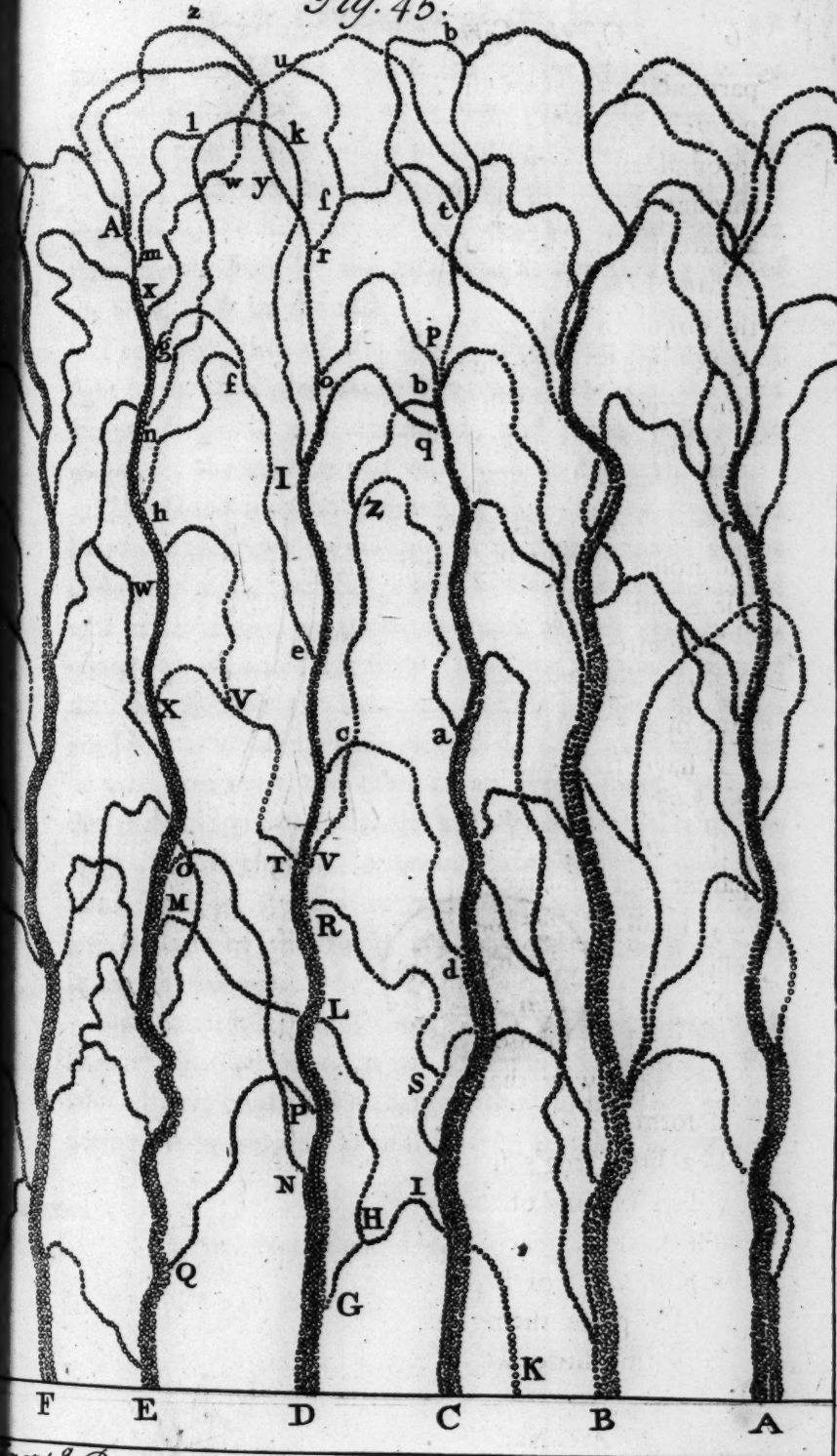
You may often observe in viewing several of those objects, the globules cannot pass through the smaller vessels, otherwise than single, and then squeezed into an oval form.

If a little frog's spawn, in the spring time, be kept a few days in some of the ditch-water, in which it is found, you'll have a great number of exceeding small tadpoles, which at their first beginning to swim, are nearly transparent; place them before the microscope in a small tube, with a little water, or in a cylindrical glass, and

you

¹ Arc. Nat. Tom. iv. Ep. 84, and 86.

Fig. 45.



you may behold the circulation of the blood in every part of the subject, and in a more particular manner in the tail, near ^k fifty vessels presenting themselves at once to view; and also the pulsation of the heart; but they grow so opaque in a day or two, that the circulation can then be only seen in the fins, and at the joining on of the head, and in the tail.

The circulation of the blood affords an entertaining sight in the thin membrane between the toes of the hind foot of frogs, if well expanded; and placed before the magnifier, the arteries and veins will be distinctly seen.

The blood may be retained in the lungs of frogs and lizards, as follows; on making an incision into the bodies of these animals, their lungs will start out, and be distended with inspired air; on these, as quick as you can, pass a waxed thread, and tie it firmly towards the upper part of the lobe, as near the heart as possible; when the lungs are dried, after being thus distended, they may be placed in parts, between the talcs of an ivory slider, and by this means you may always keep by you objects of the lungs of those animals, only remember to place their external smooth surface towards the magnifier. These several parts of the lungs are very entertaining objects in the microscope.

But the circulation of the blood is no where seen with so much satisfaction as in the mesentery of a frog. For which I have contrived an easy method to hold the animal during the operation, as will be seen in what follows.

^k Arc. Nat. Epist. 112.

The description of a new apparatus for confining frogs, mice, bats, or any other creatures of the like size, particularly adapted to the variable and improved solar microscopes.

THIS apparatus consists of a square frame of brass A, B, C, D, fig. 46. which may be taken to pieces at pleasure. It is held together at the corners, by the four pillars F, F, F, F, which also support the frame. At the lower end of the two pillars which support the corners C and D of the frame, is fixed a steel bar G H, having one of its ends made fast to one of the pillars at G, and the other end screwed to the opposite pillar by the nut H: on this square bar is fitted a sliding socket I K, to which are fixed the stems for placing it to the microscope.

When a frog is to be dissected, tie a string to each of its four legs; first having strained strings thro' some of the principal holes of the frame, crossing each other, as in the figure is represented by the small letters a b, c d, e f, g h, i k, l m, which form a kind of lattice, or couch, whereon to extend the frog. Then first put the two strings which are tied about his arms, through two holes, the nearest to the corners A, C, and there fix them with two pegs made of fur, as at n and o, in the figure. The reason why I direct his two fore legs or arms to be fastened first is, because you may with ease hold his hind legs in your hand, till the fore legs are pegged down fast; whereas if you attempt to fix the hind legs first, the creature will give such springs and starts, as will not only tire himself, and thereby prevent him from being
able

able to go through the operation, but even make it almost impossible for you to fix him to your mind. Then fix his hind legs as before directed by the pegs p, q. If now you find him not quite fast, you may make him so, by pulling out one of the pegs at a time, and straining the string a little tighter, after which replace the peg. The ends of the strings which confine his arms and legs, are represented in the figure by the letters r, s, t, v, and the frog lying upon his back.

The object being thus extended, and fastened on the frame, as above directed, open the skin of the belly, from near the anus to the throat, in the direction of the dotted line I K, by first just entering the point of a very sharp penknife at I, through the first skin only, taking care not to touch the second skin, and let the incision be no longer than the little straight stroke I w, in which thrust the probe or director, fig. 47. almost up to his throat, with the curf x y upwards, in which curf you may run the point of a pair of scissars, without being in any danger of cutting any other part of the subject, and thereby open the upper skin from I to K, then turn the director sideways from K to L, and from I to M, and give it a little snip in that direction, both at the top and bottom. Stick a fish-hook, with the barbs filed off, into each corner of the skin, first having put the strings N O, to which the hooks are tied, through any two of the holes in the frame, as at P and Q. Then by gently pulling the strings N O, the skin will readily stretch out into the direction of a square flap, as represented in the figure by the letters L M R S, and the three dotted lines which surround them.

If now you fix the frame to the microscope, you may place any part of this flap before the magnifier, either by slipping the square steel bar G H backwards and

forwards in its sliding socket I K, or else by pulling the said socket farther from, or pushing it nearer to, the pillar of the microscope, by which means, you may with the greatest ease imaginable, examine all the blood-vessels in this transparent flap or piece of skin, by sitting at a table before a window, and directing the illuminating glass, so as to fling the rays of light immediately under this part of the skin.

If the sun shines, and you have the solar apparatus before described, screwed ready in the window shutter, apply the microscope and frog to the solar part as before shewn, and after having directed the sun's rays through the tube, upon any part of the skinny flap L R S M, and placed the screen at about four or five foot from the machine, so as to receive the sun's rays, and adjusted the object to the focus of the magnifier, and distance of the screen, you will have represented on the screen, a most beautiful picture of the veins and arteries in the skin, with the blood circulating through them; in the arteries you may plainly perceive the blood stopping, and as it were receding a little at each dilatation of the heart, and then immediately rushing forwards again at each contraction; whilst in the veins it rolls on in a continual current, with inexpressible rapidity; and when the arteries are very much magnified, if you remove the screen to a considerable distance, the alternate expansion and contraction of their sides are very visible.

When you have considered this as long as you think needful, open the abdomen, and extend the muscles before the microscope, by means of the two fish-hooks, as before in the extension of the skin, and you will with pleasure view their structure, which consists of numbers of transparent strings or fibres, lying parallel
to

to one another, and joined together by a common membrane.

These strings or fibres appear through their whole length, to be made up of minute roundish vesicles; and the blood vessels which intermix with them, afford an agreeable prospect.

The next experiment is gently to draw out a part of the frog's gut, in order to apply the mesentery to the microscope, which is a most beautiful and surprising phenomena, when viewed through the microscope, as standing upon a table: but when applied to the solar apparatus before described, you may view it in so distinct and fine a manner, that no words can describe the wonderful scene which will then be presented to your sight. The blood flowing through numberless vessels at one and the same instant, in some one way, in others the quite contrary; several of the vessels may be magnified an inch in diameter, and the blood globules rolling thro' them, will appear near as large as pepper-corns, and at the same time in the minutest vessels only single globules can find a passage, and that not without putting on the form of oblong spheriods; here also in the most inexpressible manner, will be seen the pulsation and acceleration of the blood in the arteries, as before described.

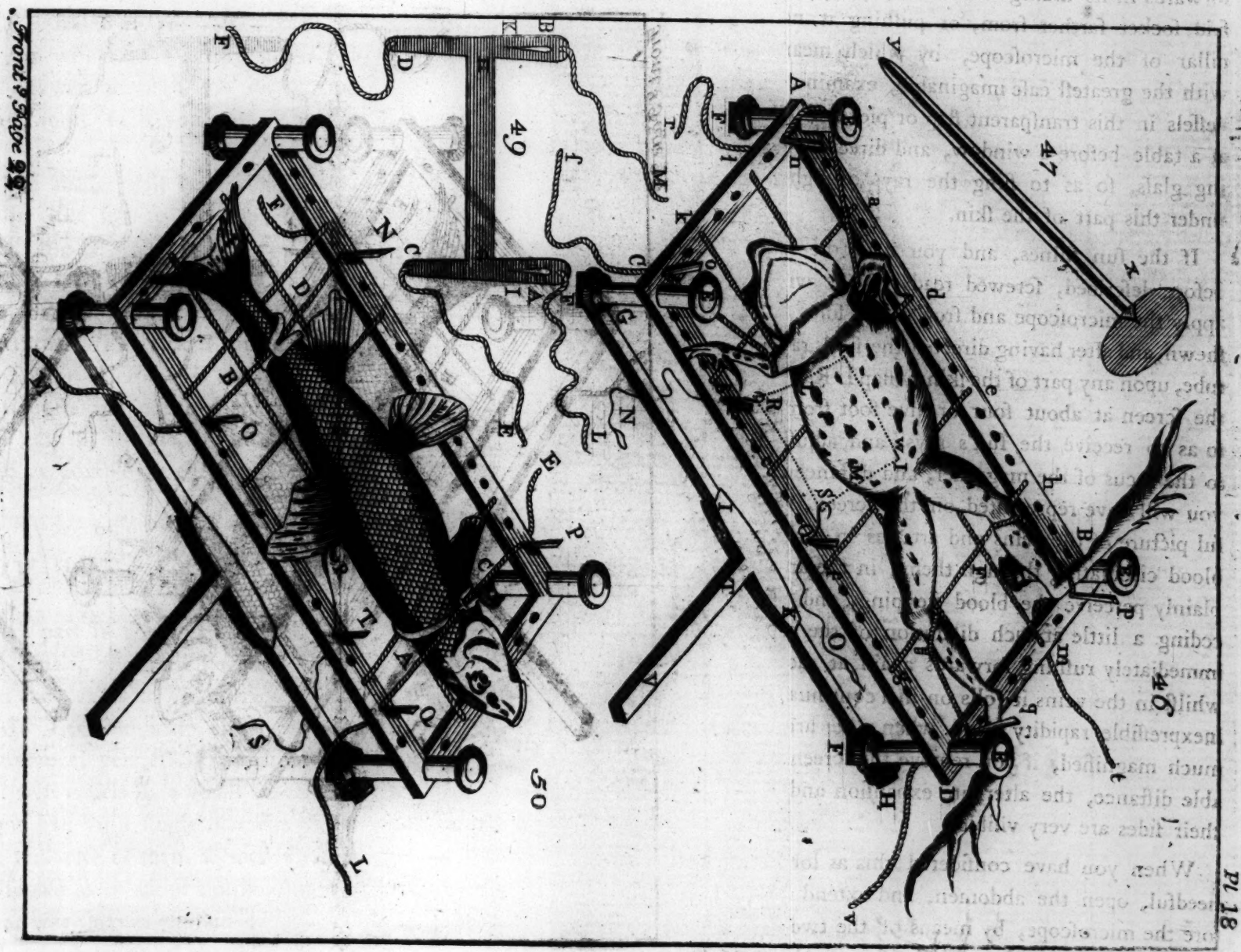
As the animal grows languid, and near expiring, the blood in the arteries will be seen to stop suddenly, and as it were seem to coagulate, and then run backwards for some time; after which it will again recover its natural course, with a great deal of rapidity.

A due consideration of these appearances, may possibly account for the intermissions, starts, and irregularities in the pulse of persons near the point of death,

Fig. 48. M, L, R, S, represents a microscopic picture of a part of the frog's gut, and mesentery extended, by means of the fish hooks R, S, M, the ends of their strings being pegged to the square frame, one of which is seen at p. B, I, K, C, is a part of the body of the frog. And I, K, that part where the belly was opened. D, E, part of the square brass frame. The shaded part within the gut, marked M, L, R, S, is called the mesentery, in which is plainly seen the blood-vessels. Those vessels, which are a little darker than the rest, are called arteries. In every one of which I plainly saw a pulse, and the blood flowing from A to R. The others are veins, through which the blood flowed in a constant stream, in the direction V, N.

As there are many small fish, whose fins are more transparent than their tails; I thought it might be acceptable in this place, to give a cut of the manner how they may be fastened upon the same frame the frog was, which take as follows.

First cut a piece of leather in the shape of fig. 49. and tie a string to each corner of it, as at A, B, C, D, and observe, that the part G H of the leather be no longer than from the fish's neck to the part where the tail begins to grow small, and cut a slit from A to I, and from B to K, then put the string C E through the slit A I, and the string D F through the slit B K, and put the fish in head foremost; after which draw the strings close, and apply it to the frame, fig. 50. fixing down the string D F to the frame by the peg N, and the string B M by the peg O. The string C E may be made fast with the peg P, and the string A L with the peg Q, in which position the fish cannot possibly get away, but on the contrary will lie exceeding quiet: then may you stick a fish-hook to the thick part of its fin at R, and stretch it out by drawing



drawing the string R S gently, and then making it fast by the peg T.

After which place the frame to the microscope, as above directed; and you will have a beautiful prospect of the circulation, if viewed through the microscope upon a table; but much more so if you apply it to the solar apparatus.

I hope by this time the reader will be enabled to fix any other subject of the like size to the apparatus, in order for dissection, and also be ready at applying them to the microscope, either to be looked at by the eye through the magnifiers, or cast upon a screen when applied to the solar apparatus. The reader will also perceive that none of the modern microscopes are so capable of having all sorts of subjects applied to them, as these are in an apparatus, so easy in its use, as to give gentlemen as little trouble as possible in the application of all sorts of objects.

Of Bones.

THEIR superficial part is found to consist of a vast many small vessels, and some few of a larger size; which last, when they came to the surface of the bone, appeared to Mr. Leeuwenhoek either with a membrane, or bony substance, perfectly transparent: he once discovered four or five vessels in a small piece of a shin bone of a sufficient size for a single filament of silk to pass through them, and one of them seemed to him to have a valve ¹ so disposed as to admit nothing into it, but only to let out what was therein contained.

The spongy or cellular substance on the inside of the bone consists of long particles closely united, that are

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¹ Phil. Transf. No. 366.

made up of a vast many small vessels, some running lengthways, others tending towards the sides of the bony particles, some lying parallel, and others perpendicular to the length of the bone; these last have vessels proceeding from their extremities; and others that compose the cortex, or superficial part of the bone, proceed from their sides; those long particles, which lie parallel to the length of the bone, emit vessels from their sides, that issue out through the side of the bone. It is impossible to conceive what a prodigious number of small vessels compose the cortical part of the bone, which on the spongy part in some places is no thicker than a human hair; though, in others, three or four times that thickness.

The periosteum is united to the cortex of the bone, not only to the outside of the cortex, but even by entering into its very substance in several places, and is joined thereto by the vessels which proceed from the bone.

Fig. 51. represents a small part of the bone with the periosteum adhering to it; A B C D E F shews the bony part, B G H I E the periosteum, in which all the small vessels are represented by dots. In other places where the thickness was twice as much, not only those vessels that had been transversely cut, and consequently represented by many points; but also many other vessels running lengthways, as in fig. 52. L O P Q N M and that part represented by B G H I E, fig. 51. are not entirely membranous, but really bony. K L M N A represent the bony part, in which though no pores or vessels are here represented, yet it is full of openings. Fig. 53. R S W X T V represents a part of another bone, S W X T the periosteum, which in this place was no thicker than a large hair of a man's beard; but in another part of the same, and at a small distance, it was four times that thickness. In another piece of bone so placed before the
microscope

microscope as to shew only the periosteum and muscular fibres, which were cut transversely, and appeared to be surrounded by fibrils of the periosteum, as in fig. 54. where Y Z A B is the periosteum, and Z C D A are the fleshy fibres cut transversely; this was part of a rib taken from a fat ox.

It appears therefore from Mr. Leeuwenhoek's observation on bones of all kinds, that they do consist of exceeding small vessels, arising from the inner hollow or spongy part of the bone, and passing through the superficial or cortical substance, enter the periosteum; and from thence are continued farther into the body, even to the remote parts thereof. Hence it is, that in a healthful body there is a constant supply of an oily substance conveyed into the bones; which again is constantly carried out from the bones by means of these vessels into all parts of the body, even to the extremity of the fingers. He examined a very small piece of the solid part of the shin-bone of an ox, and found it to consist of four sorts of tubes, perforated lengthways. The first sort so small and so closely united, as scarce to be discernable in a transverse section of it. The second sort of tubes (some of which are four, some six times larger than the first) are also difficult to be discover'd; because in cutting or shaving the bone, although the knife was sharp, it destroyed and broke many of the tubular parts, which shut up their apertures. The third sort greatly exceed those of the second, but were also difficult to be discerned, because the knife tore some of them in cutting; yet notwithstanding he was persuaded, that bones are composed out of successive additions of rings of tubes, in the same manner as wood is. The fourth sort are much larger than these, and fewer, as will appear in fig. 62. whereof M represents a very small piece
of

of a thin-bone, which when viewed by the naked eye, appeared no bigger than the spot, fig. M.

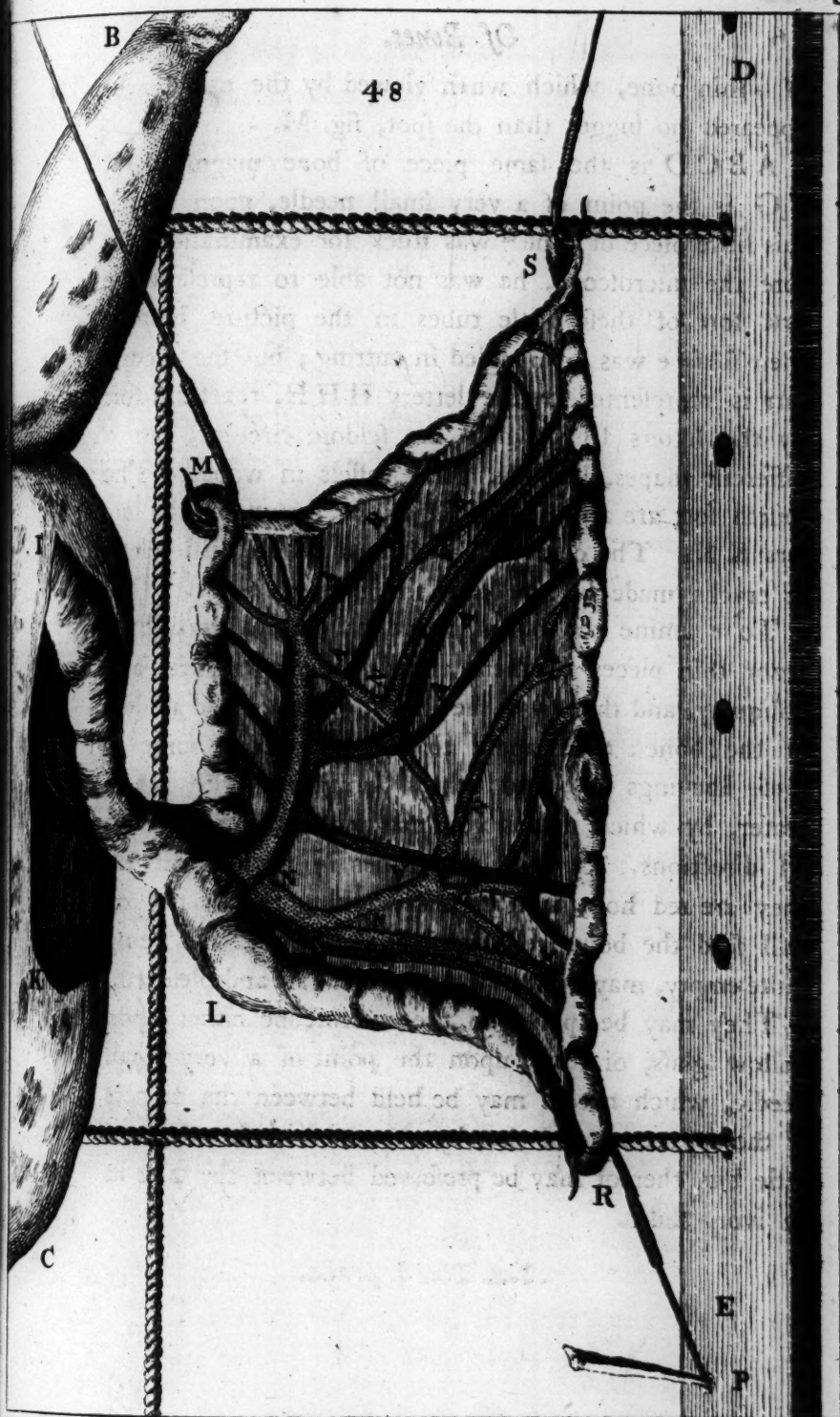
ABCD is the same piece of bone magnified, EFG is the point of a very small needle, upon which this little piece of bone^m was stuck for examination before the microscope, he was not able to represent the first sort of these little tubes in the picture, because their surface was so mangled in cutting; but the second sort is represented by the letters HHH, the third sort by the letters III, which are seldom circular, but of different shapes, like the great vessels in wood. The fourth sort are a great deal larger, as shewn by the letters KK. The curved lines L and M are little clefts or cracks made by the knife in cutting.

To examine the bones, shave off with a very sharp razor thin pieces of them crossways, lengthways, and obliquely, and that from the inside, outside, and middle of the bone: then apply to the microscope some of these shavings dry, and others moistened with warm water, by which means you may view the vesicles in all directions. Or put the bones in a clear fire till they are red hot; then carefully taking them out, you will find the bony cells perfect and entire, and being quite empty, may be view'd with great ease and pleasure.

They may be applied to the microscope either upon hollow glass, or stuck upon the point of a very small needle, which needle may be held between the nippers of the apparatus, and thereby examined with ease, and little bits thereof may be preserved between the talcs in an ivory slider.

^m Arc. Nat. Tom i. p. 200.

48



Of the muscular or fleshy fibres of animals.

MR. Leeuwenhoek hath discovered each muscular fibre to be made up of smaller fibrils, which, notwithstanding their smallness, he plainly discern'd to be vascular, for on cutting a-cross their length, the light might be seen through their apertures; but if he cut them ever so little obliquely, could see no light. He also observed the structure of the fibres in the flesh of an ox, and of a whale, but plainer in that of a whale; the fibres of the other being more compact and close; and found also that the fibres of a mouse were of the same size as ⁿ those of an ox; from whence he concludes, the different size of animals is entirely owing to the number and length of their fibres. These fleshy fibres appear throughout their whole length, to be encompassed as it were with spiral circumvolutions as is exactly represented in fig. 69.

Which disposition seems to be wonderfully contrived for readiness in the distension and contraction of the fibres. Two of those fleshy fibres are represented by GH, and IK, fig. 68.

To view the muscular fibres with the microscope, cut off a piece of dried flesh or fish, as thin as possible, and lay it upon a glass slip, and moisten it with warm water, which drying soon away, will leave the vessels open and distinguishable. As the learned differ in their opinions with respect to the figure and structure of these little vesicles, I shall leave it to the curious for farther examination.

Mr. Leeuwenhoek informs us, that the fleshy fibres in insects are no less visible than those of larger creatures,

ⁿ Arc. Nat. Tom. iii. p. 108.

tures, which he found by cutting off the legs of flies, gnats, ants, &c. in all which he could plainly distinguish the circular wrinkles or circumvolutions encompassing the fibres, as in fig. 69.

Upon cutting the fleshy fibres of a whale, lengthwise, and a-cross, ° he plainly discovered each particle, or fleshy fibre, to be enveloped in a fine thin membrane. It appear'd in the microscope, as represented fig. 55. in which the parts lay so close together, that their encompassing membranes, represented by the black lines, were but just discernable; some however appear'd larger than others, and these, ¶ if attentively view'd, seem'd to be divided into a great many others, some also cut transversely, and crowded so close together, that their figure, as well as size, was very different. Fig. 56. represents a thin slice of the flesh of a whale, which after having been made thoroughly wet, and applied to the microscope, appear'd as in the figure. Upon letting the moisture evaporate from these slices, the particles became much smaller, and the membranes, with which each was encompassed, were very visible. Fig. 57. represents a piece of the same flesh, wherein the particles seem'd to touch, but on their being dried, shrunk up, from the surrounding membranes, whereas the membranes themselves could not shrink, because they were all join'd together. All along these fleshy fibres ¶ run membranes about the thickness of an hair, and distance of a grain of sand; from these larger membranes, other parts were spread, dividing each fibre into a great many fibrils; from whence we may say, that each fleshy fibre, no bigger than an hair, is a small muscle encompassed with its peculiar coat or membrane. Fig. 58. represents a small piece of these fibres greatly magnified.

° Epist. Phys. p. 3. ¶ Ibid. p. 4. ¶ Phil. Trans. No. 39.

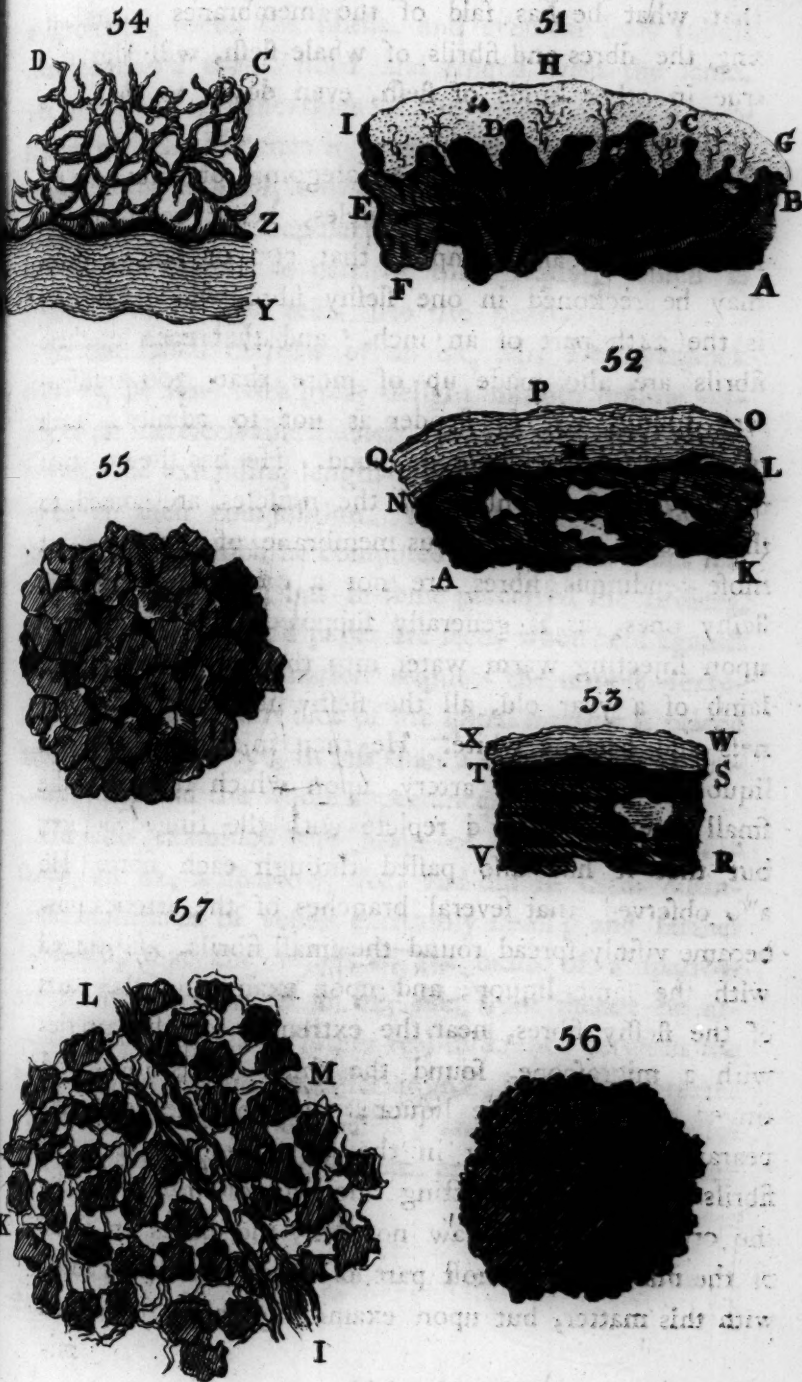
magnified. On moistening again the fibres represented by the two last figures (that were dried and shrivell'd up) they became so distended, as to fill up the spaces between the membranes, and re-assume the shape they had before they were dried. Among several little pieces of flesh, moisten'd as above, and placed before the microscope, there was one, whose particles were not separated upon drying; suppos'd to be owing to the splitting and tearing asunder of a large membrane, which run through its middle, as represented in fig. 59. by Q R S T V W, where between S T and V the dried particles remain unseparated, S W shews the thick membrane that divided this piece about the thickness of an hair, that sent out a branch at T, and at W was split into two. Fig. 60. represents a very small piece, consisting only of five fibres cut lengthwise, as they appear'd through the microscope; between C and F may be seen the little membranes which encompass the fibrils, but are here torn asunder. Fig. 61. exhibits four small fibrils of a piece of flesh of another whale, by which it plainly appears, that the diameters of these fibres are as small again as those in the foregoing figure, therefore they must be four times as big as these; as each fleshy fibre is composed of a great many smaller fibrils, we may imagine each of these inclosed ones, to consist also of others of the like nature.

Mr. Leeuwenhoek, on viewing several small fibres of ox flesh, observed each of its contained fibrils to be encompassed with a thin membrane; but could not shew these membranes so distinctly to others in this flesh, as in that of a whale; because the parts of the first are of a texture much more compact and close, than those of the latter; for which reason they do not shrink so much in drying. And is also of opinion, that

that what he has said of the membranes encompassing the fibres and fibrils of whale-flesh, will also hold true in other kinds of flesh, even down to that of a rat or mouse.

Mr. Muys confirms the foregoing observations on the fleshy fibres of the muscles, being composed of smaller fibrils, and computes that 500 or 600 of them may be reckoned in one fleshy fibre, whose diameter is the 24th part of an inch, and that each of these fibrils are also made up of more than 300 transparent tubuli, but so slender as not to admit a 24th part of a single globule of blood. He has shewn, that though the fleshy fibres of the muscles are joined to the tendons, and tendinous membrane of a muscle; yet those tendinous fibres are not a continuation of the fleshy ones, as is generally supposed. He found that upon injecting warm water into the crural artery of a lamb of a year old, all the fleshy fibres lost their redness and become white. He then injected a colour'd liquor into the same artery, upon which not only the small arteries appear'd replete with the tinged liquor, but that it had also passed through each fibre. He also observed, that several branches of the arteries now became visibly spread round the small fibrils, and tinged with the same liquor; and upon examining the parts of the fleshy fibres, near the extremity of the arteries with a microscope, found the small fibrils filled and tinged with the same liquor; and not the least appearance of the liquor in the interstices between the fibrils. And upon injecting another colour'd liquor by the crural artery, he saw not only the fibres in some of the muscles, and most part of them in others, filled with this matter, but upon examining them in a good

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microscope, found the fibrils, and even the least tubuli that compos'd them, filled and tinged with the same, yet the small ramifications of the nerves appear'd perfectly white. Whence it appears, that the small tubes which form a fibril, are really hollow; and that the extremities of the capillary arteries open into them, and empty therein a part of their liquor, which is re-conveyed by the veins into the heart.

In the spinal marrow of an ox, Mr. Leeuwenhoek tells us, he saw with great delight minute hollow vessels of an inconceivable fineness, invested with their membranes, and extending length-wise parallel to each other, make up their composition. He did not only discern their cavities, which he computed to be three times less than their diameters, but in some perceived the orifices, as the holes in a prick'd paper are seen, when held against the sun. This examination requires the utmost dexterity. For after a thin slice of the spinal marrow is placed before the microscope, in less than a minute's time it becomes dry, and the whole appearance lost *.

He also examined the brain of an Indian hen, a sheep, an ox, a sparrow, &c. and did in them distinguish multitudes of vessels extremely small; and farther observ'd, that the vessels in the brain of a sparrow are no smaller than in an ox, and from thence he argues, that there is no other real difference between the brain of a larger and a smaller animal, but only a greater or a smaller number of vessels; and that the globules of the fluid passing through them, are in both of the same size.

* Arc. Nat. Tom. iii. p. 310, 355, 440: * Ibid. Tom. i. Part i. p. 38.

Of Hairs.

FROM Malphigi's curious observations of the hair, we are informed, that they are compos'd of a number of extremely minute tubes, which are most distinguishable near the end of the hairs in a horse's main and tail, and in the bristles of a boar, wherein those tubes so manifestly appear, that he could sometimes reckon above twenty of them; and in the hedge-hog's prickles, he plainly saw those tubes, together with medullary valves and cells.

That which this sagacious and not enough to be commended observer, took notice of in the structure of hair, and its parity to the spines, ^a is observably true in some measure in the hairs of cats, rats, mice, and in divers other animals, which look very prettily when viewed with a good microscope.

Fig. 63. A, B, C, represents three cylindrical pieces of human hairs; they are transparent throughout their whole ^x length; and are composed of small long tubular fibres, encompassed with a kind of bark; from which structure, the ends of long hairs when split, appear like a stick shrivelled with beating, some of them in men, horses, sheep, hogs, &c. having six or more splinters.

Fig. 64. represents a cylindrical piece of the hair, or bristle of an hog, which is neither perfectly round nor sharp edged, but prismatical, with divers sides and roundish angles.

Part of a whisker of a cat cut transversly, is represented by the short cylinder, fig. 65. which seemed

^a Derham's Phis. Thef. p. 220. ^x Hook's Microgra. 1st Ed. p. 158.

ed to have a large pith in the middle, like that of elder.

The hairs of Indian deer appear perforated from side to side. The long hairs of horses as at D E F, fig. 66. seem cylindrical, and somewhat pithy.

The hair of a mouse seems to be one single transparent tube, with a pith, made up of a fibrous substance, running in dark lines, in some hairs transversely, in others spirally; these darker medullary parts are no other than small fibres convolved round; and lying closer together than other parts of the hair; they run from the bottom to the top of the hair, and it is apprehended that they run round in a screw-like fashion. A B, fig. 67. represents that part of the hair which grew near the skin, the middle part of the same hair is shewn at C D, and the point of it at E F.

Hairs taken from the head, the eye-brows, the nostrils the beard, the hand, and other parts of the body, appear unlike, as well in the roots as in the hairs themselves, and vary as plants do of the same genius, but of different species.

Hairs have each a round bulbous root, which lies pretty deep in the skin, being planted in the pyramidal papillæ, and by this imbibe their proper food from the adjacent humours, and, as hinted above, their extremities split or divide in two or three branches, especially when kept dry, and left to grow too long; so that what to the naked eye appears only a single hair, to the microscope seems a brush.

γ Arc. Nat. Tom. iii. p. 47.

Of the scales in the human skin.

THE cuticula, scarf skin, or outward covering of the body, is remarkable for its scales and pores.

The scales grow upon our bodies, just as the scales grow upon the external skin of a fish, ^z and are placed as in fishes three deep, i. e. each scale is so far cover'd by two others, that only a third part thereof appears, as at M, fig. 70. their lying over one another, may be the cause why the skin of the body appears white; for about the mouth and lips, where they only just meet together, and do not fold over, the blood-vessels are seen through, and the parts look red.

The perspirable matter is supposed to issue between those scales, (which lie over the pores or excretory vessels, through which the watery and oily humours perspire) and may find vent in an hundred places round the edges of the skin.

A piece of skin taken from between the fingers, neck, arms, forehead, or any other part of the body which is not hairy, serves best to shew the scales: or if they be scraped off with a penknife, and put into a drop of water, and so applied to the microscope, they will be seen to good advantage, as at L, fig. 70. and generally consist of five sides.

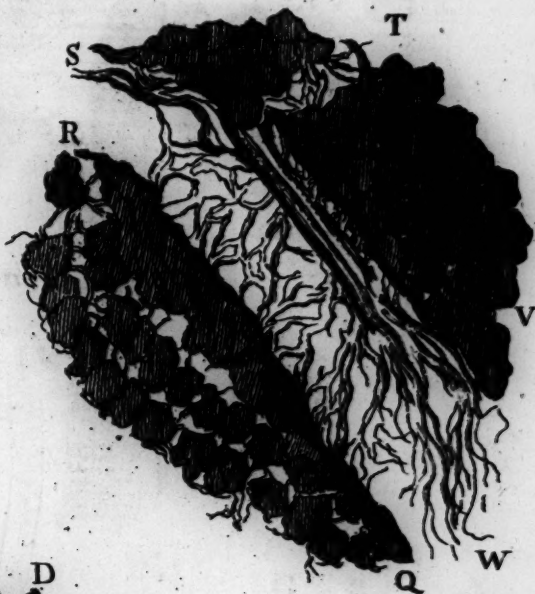
Mr. Leeuwenhoek tells us 200 of them may be covered with a grain of sand ^a, so that if a grain of sand can cover 200 of those scales, it will also cover ^b 20,000 places through which perspiration may issue.

^z Phil. Transf. No. 159. ^a Arc. Nat. Tom. i. Par. II. p. 208. ^b Arc. Nat. Tom. iv. p. 48.

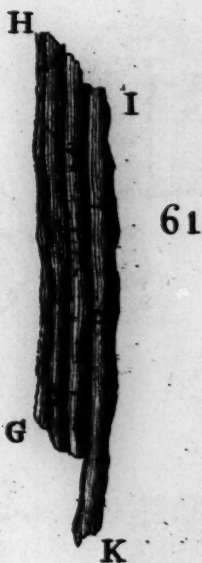
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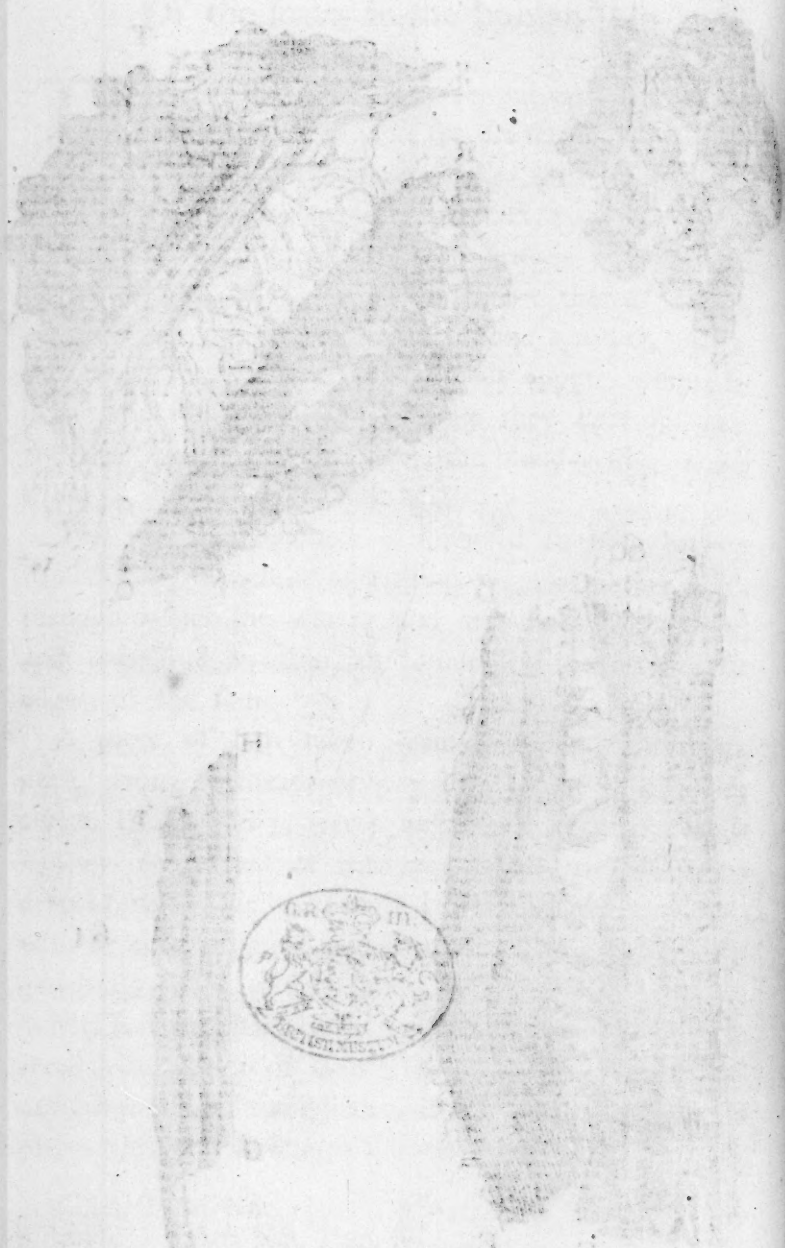
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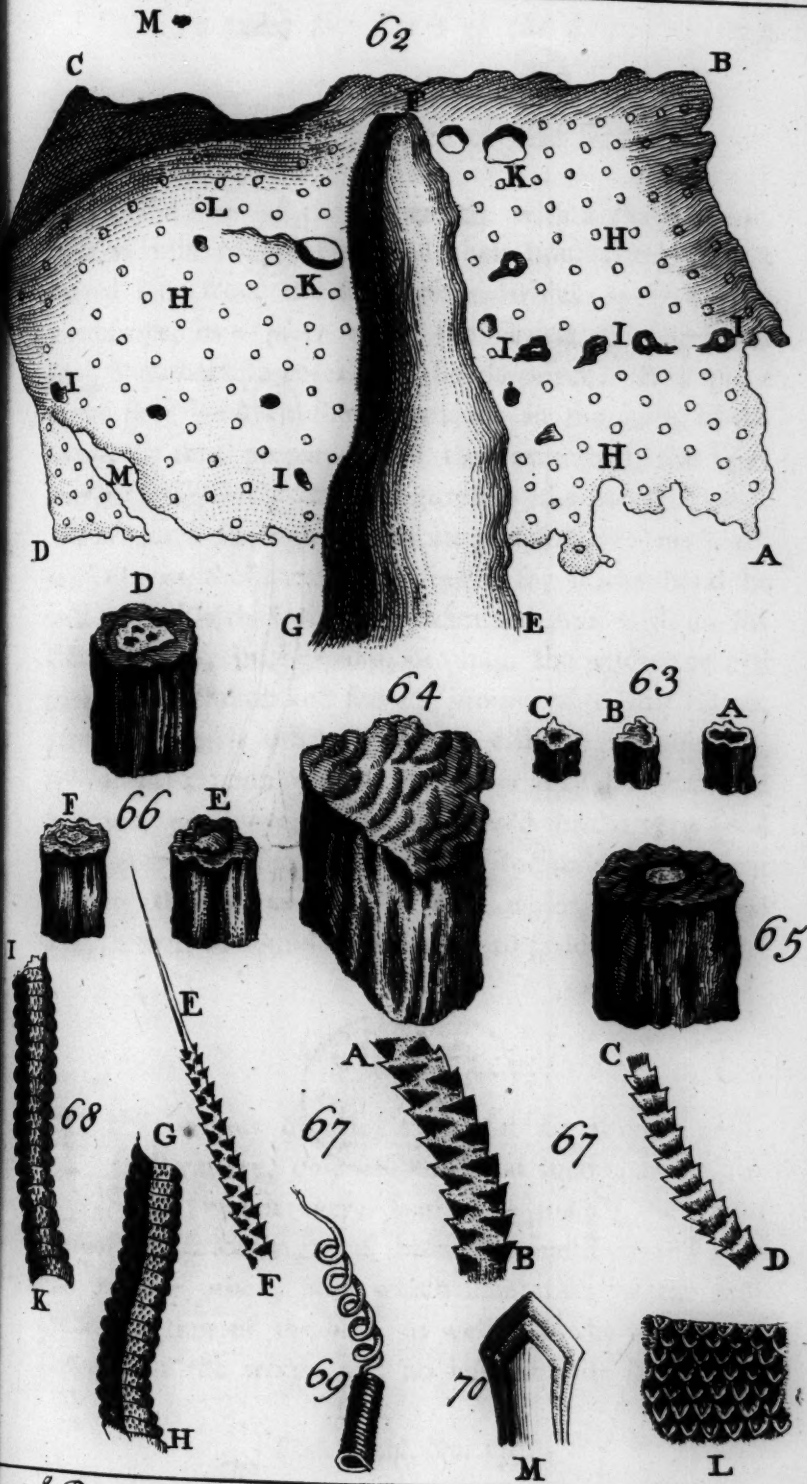
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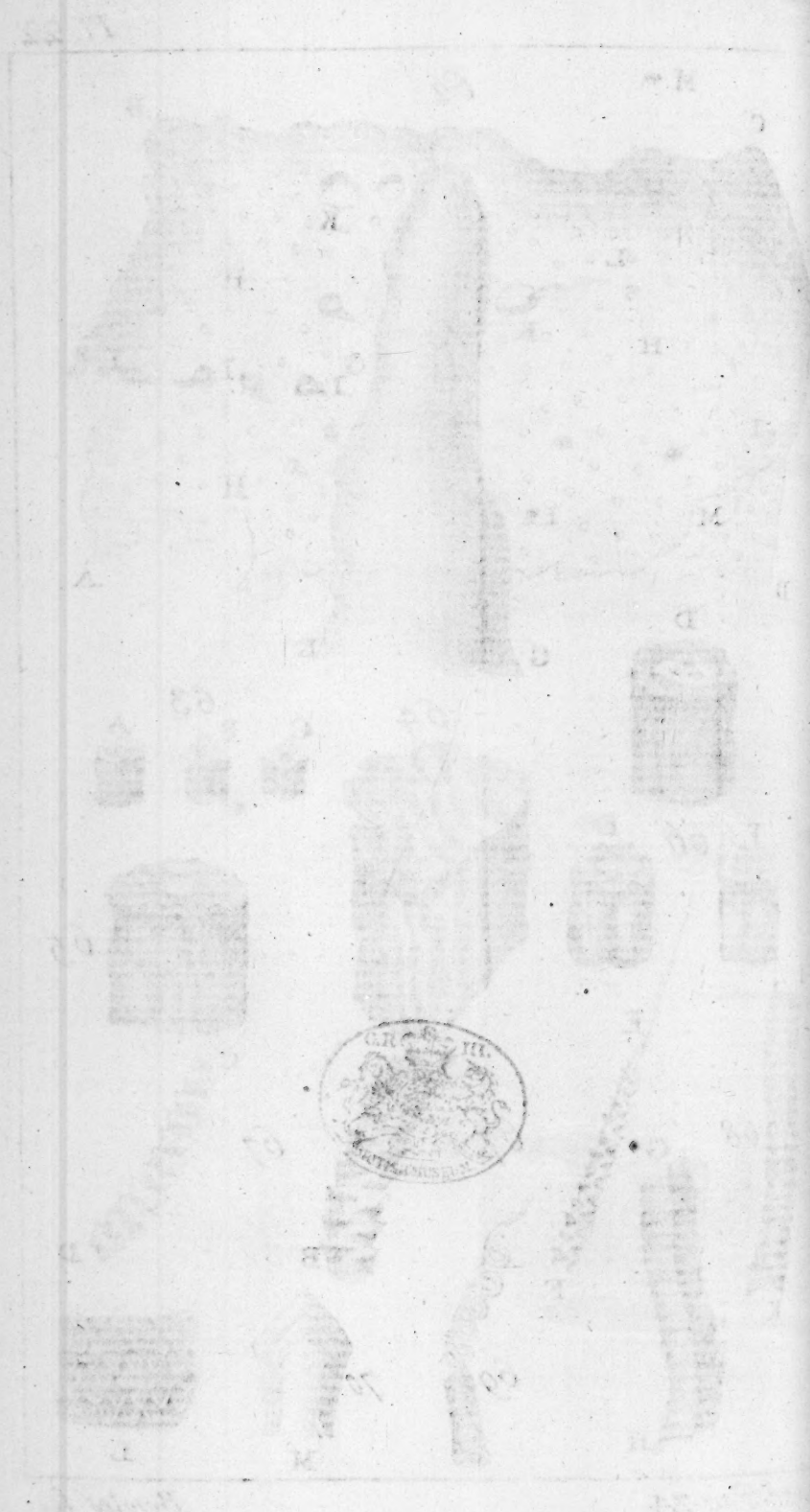


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To view the pores of the skin.

CUT a slice of the upper skin with a sharp razor, as thin as possible; and then immediately cut a second slice from the same place, which apply to the microscope, in a piece about the bigness of a grain of sand, innumerable pores will be perceived. If a piece of the skin between the fingers, or in the palm of the hands, be thus prepared, and then examined, the light may very pleasantly be seen through the pores.

The pores through which we perspire, are most remarkable in the hands and feet; for if the hand be well washed with soap, and examined but with an indifferent glass, in the palm, or upon the ends and first joints of the thumb and fingers, innumerable little ridges, parallel to each other, of equal distance and bigness, will appear; upon which the pores may be perceived by a very good eye, but when view'd thro' a very good glass, every pore seems like a little fountain, with sweat standing therein, as clear as rock water, and if wiped away, it will be found immediately to spring up again.

Of feathers.

THE feathers of most sorts of birds afford a beautiful variety, observable in that incomparable curiosity with which every feather is made; the vanes thereof are curiously gaged, broad on one side, and narrow on the other; both which administer to the progressive motion of the bird, as well as to the union and closeness of the wing; and no less exquisite is the tex-

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trine art of the plumage also, which is so curiously wrought, and so artificially interwoven, that it cannot be view'd without admiration, especially if the eye be armed with a microscope.

Mr. Hook observes, that the make and texture of their downy parts are most admirable; for, says he, there is scarce a large feather, but contains near a million of distinct parts, and every one of them regularly shaped; with his naked eye he counted 300 of the long downy Branches on one side, and an equal number on the other side, of more stiff and shorter branches, in a middle sized goose quill, and examining many of those long downy branches with his microscope, found several of them to contain near 1200 small leaves, such as A B of fig. 71. and as many stalks on the other side, such as A C, of the same figure; each of these branchings A B, seemed divided into 16 or 18 small joints, out of most of which grew long slender fibres, as are expressed in the figure, by a b c d, several of which terminated in a hook; those on the other side were much shorter, the stalks A C were divided into as many knotted joints, but without strings or hooks, being divided at D into two parts, one side extended from D towards C, in length equal to A C, the other side at D was very short. The transverse section of these stems or branches, were shaped like E F G H, whose covering appear'd like horn, and the pith like that of the main stem of the feather; these stems or downy branches are so ranged, that the leaves or hairy stalks of the one, lie at top, or are incumbent on the stalks of the other, and cross each other, much after the manner of fig. 72. by which means, each of those little hooked fibres get between the naked stalks, which being full of knots, and a pretty way disjoined, the two parts are so closely and admirably

admirably wove together, as to resist the air; and are so extremely small, that the 500th part of an inch exceeds them in thickness.

The parts of the feathers of a peacock, appear through the microscope no less beautiful than the whole feather does to the naked eye; the stem of each feather in the tail, sends out multitudes of lateral branches; such as AB, of fig. 73. which represents one thirty second-part of an inch, each of these lateral branches emits numbers of little sprigs or hairs, on each side, as CD, CD, CD, each of which in the microscope appear to consist of a multitude of bright shining parts, which are a congeries of small plates, as e, e, e, e, e, &c. each shaped like a, b, c, d, of fig. 74. a c being a prominency or stem; and d and b the corners of two small thin plates, that grow into the small stalk in the middle, making a kind of little feather, and lie close to, or rather upon each other in the manner of tiling; they grow on each side of the stalk, opposite to each other, by two and two, in the manner expressed by fig. 75. the tops of the lower ones covering the roots of those next above them; the under sides of each of these plates are very dark and opaque, reflecting all the rays cast upon them; much like the foil of a looking-glass; but their upper sides seem to consist of a multitude of exceedingly thin plated bodies, lying close together, and thereby like mother of pearl shells do not only reflect a very brisk light, but even tinge that light so reflected in a most curious manner, which by various positions of the light, reflect first one colour and then another, in a most vivid and surprizing manner. And that these colours arise only from the refraction of light, he found that wetting the colour'd parts with water, destroyed their colours, and though he was not able to see those hairs at all

transparent in common light, yet by looking at them against the sun, found them to be tinged with a darkish red, not at all resembling the curious greens and blues they exhibit.

The changeable colour'd feathers of ducks, and several other birds, he found upon examination with the microscope to proceed from the same causes and textures.

The best way to apply one of these small downy fibres to the microscope, is to pinch them between the nippers.

Mr. Derham, in his description of the vanes of a flag feather of a goose's wing, observes these two particulars, 1. That the exterior or narrow vanes bend downwards; the interior wider vanes upwards; by which means they catch hold, and lie close to one another, when the wing is spread, so that not one feather may miss its full force and impulse. 2. That the very tips of these feathers are also neatly sloped to a point, towards the outer part of the wing; the exterior vanes towards the body.

The vane or web of a feather, consists of several laminæ, which are thin, stiff, and somewhat of the nature of a thin quill; towards the shaft of the feathers (especially in flag feathers of the wing) those laminæ are broad, and of a semicircular form, which serves for strength, and also for shutting these plates close to one another, when impulses are made upon the air. Towards the outer part of the vane, these laminæ grow slender and taper; on their under side they are thin and smooth, but are parted into two hairy edges on the upper; each side having a different sort of hairs laminated or broad at bottom, and slender and bearded above the other half.

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The uppermost edge of one of the laminæ, with some of the hairs on each side, is represented in fig. 76. as it appears a little magnified in the microscope. These bearded bristles, or hairs, are streight on one side thereof, as fig. 77. those on the other side have hooked beards on one side of the bristle, and streight ones on the other, as fig. 78. both these bristles magnified (only scattering and not close) are represented as they grow upon the upper edge of the laminæ f t, in fig. 76. and in the vein, the hooked beards of one laminæ, always lie next the streight beards of the next laminæ, and by that means lock and hold each other, and by a pretty mechanism, brace the laminæ close to one another. And if at any time the vane happens to be ruffled and discomposed, it can by this easy mechanism, be reduced and repaired.

Of flies.

THE common fly is an object beautifully ornamented with a mixture of silver and black, and thick set with bristles, pointing from its head towards the tail; in its head are two large hemispherical eyes, embroidered with silver hairs, a wide mouth, an hairy trunk, and a pair of short horns. Its trunk has two parts folded over each other, and sheathed in the mouth, whose extremity is sharp. In those flies which are of a light colour and more transparent than others, the motion of the intestines may be plainly seen, and also the motion of the lungs, as they alternately dilate and contract themselves.

In general, the female fly is supplied with a moveable tube at the end of her tail, by the extension

of which she can convey her eggs into convenient receptacles, such as may afford a proper nourishment to the young. From these eggs proceed minute maggots or worms, represented in fig. 79. which after feeding voraciously for some time, arrive to their full growth, and are transform'd into little aurelias, as in fig. 80. whence after a longer space of time, they issue forth perfect flies, as fig. 81.

Of the feet of flies, &c.

FIG. 82. A, is a microscopic representation of the foot of a fly, in which is seen three of its joints, the two talons, and the two skinny palms or soles in a flat posture. Fig. 82, B, shews only one joint, the talons, &c. in another posture, which is so admirably and curiously contrived, as to enable the flies to walk against the sides of glass, and to suspend themselves under the surface of a ceiling, with the greatest seeming facility and firmness. The two talons AB, AC, are very large in proportion to the foot; the biggest part of them from A to II, is all hairy, their points C and B smooth, and bending inwards. Each of these talons are jointed at A, so that the fly is able to open and shut them at pleasure: the claws readily enter the pores of most substances, at which time, as the fly endeavours to shut them, the claws CB, do not only draw towards, but fix each other; and also draw the whole foot GGADD forward; so that on a soft body, the points GGGG (of which the fly has about ten to each foot) enter. This is sensible to the naked eye, in the feet of a chaffer, and if you suffer him

to creep over the hand, he makes his step as sensible to the touch also.

But as this contrivance often fails the chaffer, so would it the fly, had not nature furnished his feet with another curious contrivance, which is the palms or soles DD. They are two small, thin, flat, and horny substances, that arise from the under part of the last joint of the foot, and are seemingly flexible; so that their two sides do not always lie in the same plane, but may be shut closer, and as it were grasp a body of themselves: besides, the under sides of these soles are all beset with small bristles, like the wire teeth of a card, whose points tend forward. Hence the talons drawing the feet forward as before, and these soles being applied to the surface of the body, with all its points looking the contrary way, if there be any irregularity, or yielding therein; the fly suspends itself very firmly and easily. That the fly is enabled to walk on glass, proceeds partly from a ruggedness of the surface, or a kind of tarnish or dirty smoaky substance, adhering to the surface of that very hard body; and though the pointed parts cannot penetrate, yet they may find pores enough in the tarnish, or at least make them. This structure Mr. Hook surveyed with great diligence, because he could not comprehend, that if there was any such glutinous matter in those supposed sponges (as most that have observed that object in a microscope, have believed) how the fly could so readily unglew and loosen its feet; and also because he had found no other creature any ways like it.

A contrivance nearly alike to this is to be found in all kind of flies, and case-winged insects, and in the flea, in mites, &c. some of which have only one sharp talon at the end of each leg, which drawing towards the center or middle of their bodies, enable these exceed-

ing

ing light bodies to suspend and fasten themselves to almost any surface. This will not seem strange, if we consider first how small their bulk is when compared to their superficies, their thickness frequently not amounting to the 100th part of an inch. Secondly, their strength and agility, compared to their bulk, which in that proportion perhaps may be an hundred times stronger than an horse. Thirdly, if we consider that nature always appropriates the instruments in the most fit, easy, and simple manner possible to perform their office; which is also verified in the foot of a louse, each of his legs being footed with two small claws, with which it grasps and thereby moves itself to and fro upon the hairs of the creature it inhabits.

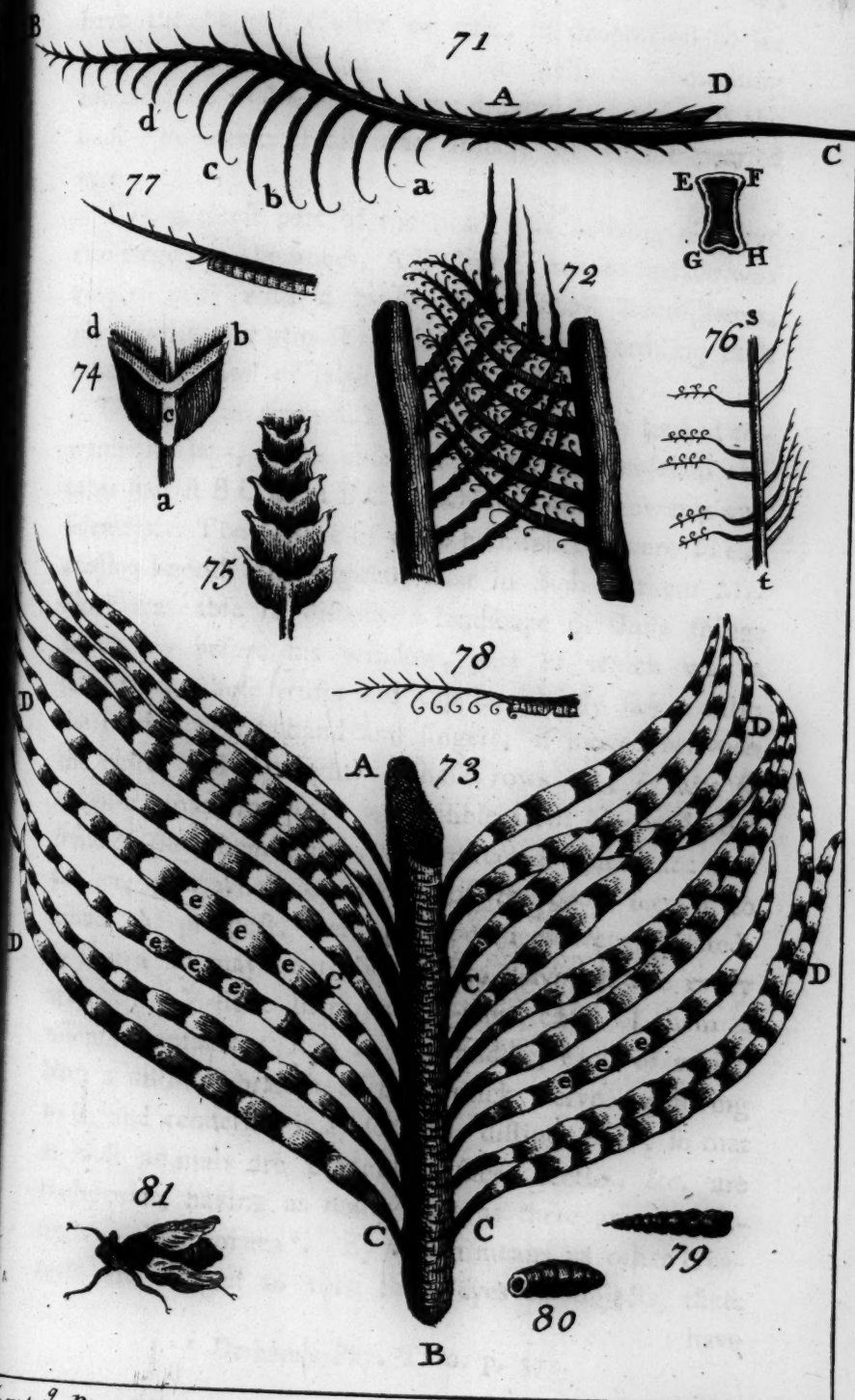
The legs of flies are best applied to the microscope, by being either stuck upon the point, or held between the nippers. Though we frequently place them between two talcs in an ivory slider.

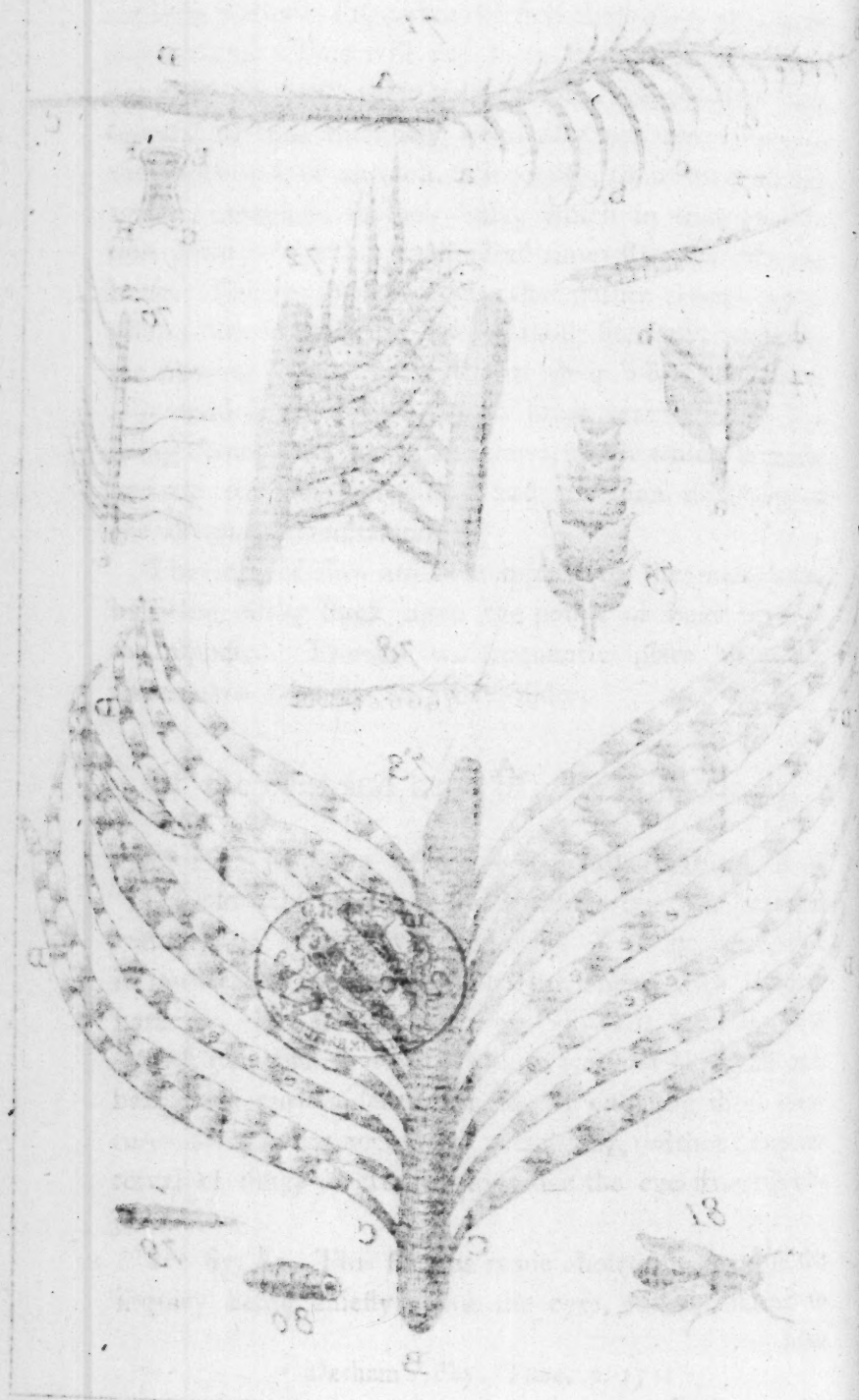
Of the eyes and head of a grey drone fly.

THE structure of the eye in all creatures, is an admirable piece of mechanism; but the beautiful contrivance of the eyes of insects is so peculiar, that it must excite our admiration; so fenced with its own hardness, that its own accurate vision is a good guard against external injuries; its outward coat being all over beset with curious lenticular inlets; enabling those creatures to see very accurately every way, without any interval of time, or trouble to move the eye towards objects^d.

See fig. 83. This fly was made choice of, because the inquiry being chiefly about the eyes, it was found to have

^d Derham's Phy. Theo. p. 171.





have the biggest cluster of eyes, in proportion to its head, of any other small fly; it inclining something towards the make of the large dragon fly, which is the most remarkable of all other insects for its fine pearled eyes.

The greatest part of the head was nothing else but two large protuberances, A B C D E, whose surface was covered over with a multitude of small hemispheres, placed with the utmost regularity in rows, crossing each other in a kind of lattice-work.

That half of them C D E, C D E, which looked towards its legs, were observed to be smaller than the other half A B C E, A B C E, which looked upwards and sideways. The surface of these hemispheres were so exceeding smooth and regular, that in each of them Mr. Hook was able to discover a landscape of those things which lay before his window, part of which was a large tree, whose trunk and top he plainly saw. Also the motion of his hand and fingers, if moved between the object and the light. These rows of eyes was so disposed, that no object was visible from his head, but some of these hemispheres were directed against it: and further, that where the trunk of the body seem'd to hinder the prospect, these protuberances were elevated, so that a fly may be truly said to have an eye every way. These little hemispheres have each of them a minute transparent lens in the middle, each of which hath a distinct branch of the optick nerve ministring to it, and rendering it as so many distinct eyes; so that as most animals are binocular, flies, beetles, &c. are multocular, having as many eyes as there are perforations in their cornea^e. By which means as other creatures are obliged to turn their eyes to objects, these have

^e Derham's Phy. Theo. p. 372.

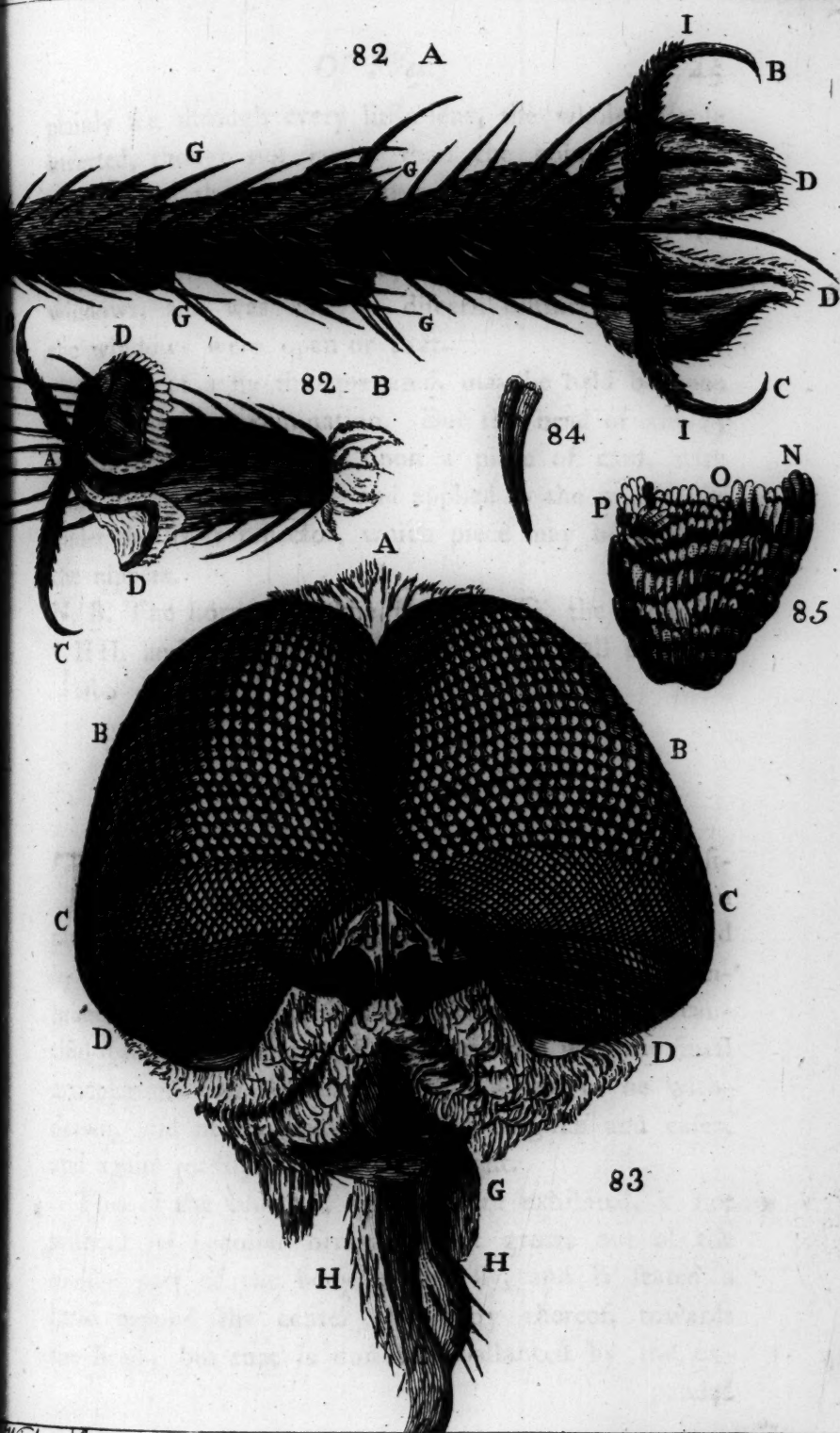
have some of their eyes ready placed towards objects nearly all round them.

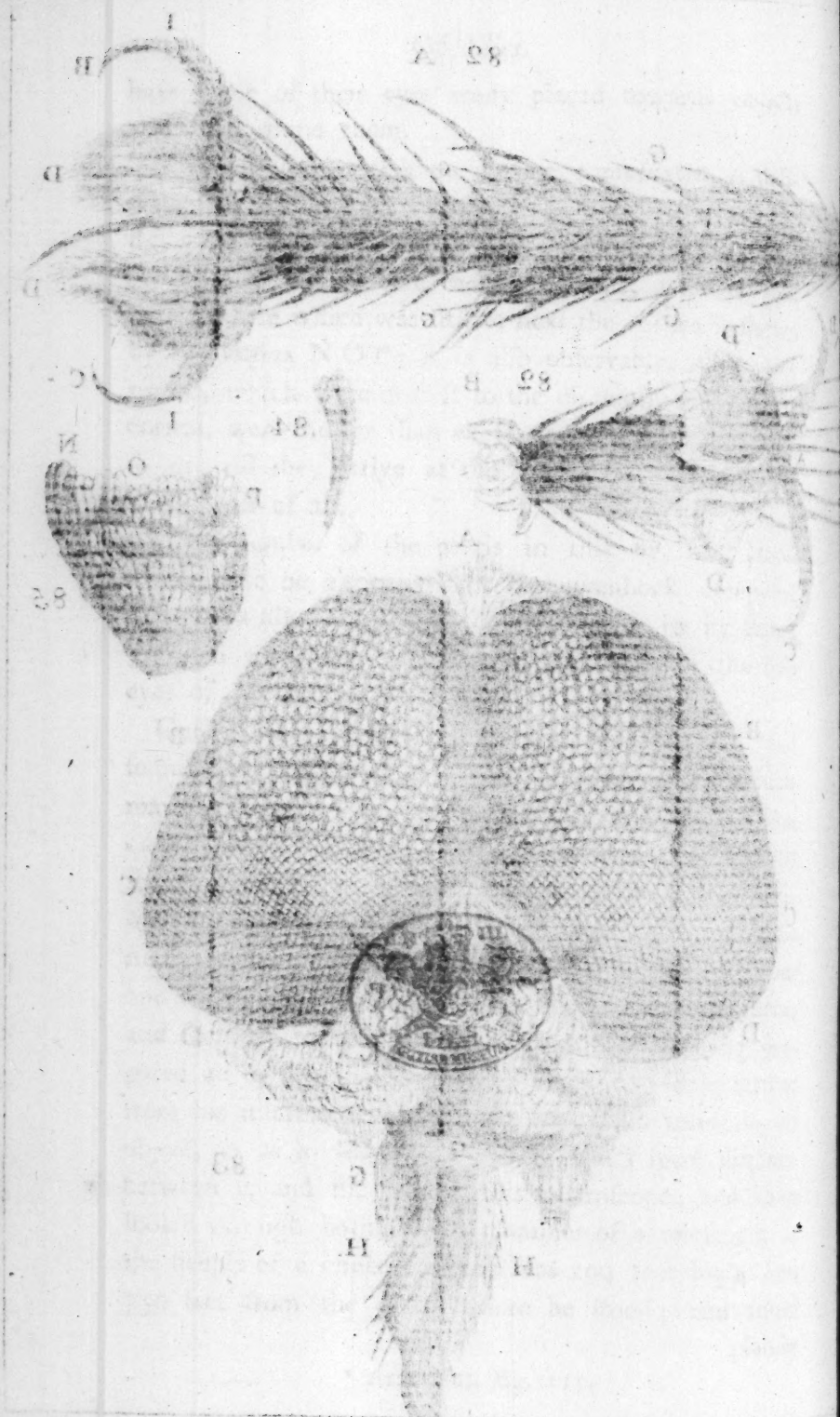
Two of these optick nerves are represented as delineated by Mr. Leeuwenhoek, in fig. 84. And in fig. 85. are exhibited ^f a great many of them in a cluster, as they appeared before the microscope, whereof that part of them which was situate next the cornea is shewn by the letters NOP; it is also observable, that those nerves, which were nearest to the circumference of the cornea, were shorter than those next within them, and so on, till they arrive at the central nerve, which is the longest of all.

The number of the pearls in this fly, Mr. Hook reckon'd to be 14000. Mr. Leeuwenhoek computed 6236 in a silk-worm's two eyes, when in its fly state; 3181 in each eye of a beetle; and 8000 in the two eyes of a common fly.

Cut off the eye of any fly, and with a pencil, and some clean water, wash out all the vessels, those vessels may be examined by the microscope, and then if you carefully dry the outward covering, so as not to let it shrink, it will be rightly prepared for making experiments; and upon viewing it, we shall distinguish the numerous protuberances or hemispheres divided from one another with a small light, issuing between them, and six sides to each. Mr. Leeuwenhoek having prepared an eye in this manner, placed it a little farther from his microscope than when he would examine an object, so as to leave a right and exact focal distance between it and the lens of his microscope; and then look'd through both, in the manner of a telescope, at the steeple of a church, which was 299 feet high, and 750 feet from the place where he stood; and could plainly

^f Arc. Nat. Ep. 111.





plainly see through every little lens, the whole steeple inverted, though not larger than the point of a fine needle; and then directing it to a neighbouring house, saw through abundance of the little hemispheres, not only the front of the house, but also the doors and windows, and was able to discern distinctly whether the windows were open or shut.

An eye of a fly thus prepared, may be held between the nippers for examination. But the head of any fly is best seen when stuck upon a piece of card, with some strong gum water, and applied to the microscope under the silver reflector, which piece may be held in the nippers.

N. B. The horns FF, the feelers GG, the proboscis HH, and the hair and bristles KK, shall be hereafter described.

Of the wings of flies.

THE wings of all kinds of insects afford an infinite variety, no less agreeable to the mind, than pleasing to the eye; being distended and strengthened by the finest bones, and cover'd with the lightest membranes. Some of them are adorn'd with neat and beautiful feathers, and many of them provided with the finest articulations and foldings, for the wings to be withdrawn, and neatly laid up in their vaginæ and cases, and again readily extended for flight.

This of the blue fly, fig. 86. here exhibited, is not without its peculiar ornaments; it grows out of the middle part of the body of the fly, and is seated a little beyond the center of gravity thereof, towards the head; but that is curiously ballanced by the expanded

panded area of the wing, which consists of several bony ribs, that gave strength to the filmy parts; which are thickly beset with innumerable small bristles, intermixed with as many dark spots, which seem to be the roots of the hairs that grow on the other side.

Of other flies, some of their wings are filmy, as the dragon flies; others stuck over with short bristles, as the flesh fly; others have divided wings, as the grey and white feather'd moths; many sorts of gnats wings are adorned with rows of feathers along their ridges, and borders of feathers round their edges; some have hairs, and other hooks, placed with the greatest regularity and order. In the butterfly and some moths, there are an infinite number of small feathers, which cover both the under and upper surfaces of this thin film, not only shaped much like the feathers of birds, but also variegated with the greatest variety of curious bright and vivid colours; which is evident to the naked eye, but much more entertaining when view'd through the microscope; by which we are informed, that these curious colour'd minute feathers end in quills, and are placed in orderly rows with great exactness, as the holes they come from shew when they are rubb'd off.

Fig. 87. represents a small piece of a butterfly's wing; A B shews one of those bony ribs that gives it strength, along whose sides are supposed to branch out various blood-vessels, conveying nourishment to the intermediate parts; although no circulation can be discern'd therein, we can scarce doubt but that a continual supply of juices must be carried on to these minute quills, hairs, and bristles; C, C, C, exhibits three of these single plumes, with their quills adhering to the transparent membrane of the wing, in which membrane

brane G, G, G, when divested of its feathers, may be seen the orders of pits or holes where the quills are rooted, and from whence they shoot; D, E, F, shews a few of the feathers exactly in the form as they cover the whole wing.

Some flies have hairs, and all the scarab kind have elytra, or cases, into which their wings are folded and preserved, till they want to employ them, as in fig. 110. some of these cases reach almost to the extremity of thair tail, as in most kinds of beetles; and in others are very short, as in the earwigg. They do by a very curious mechanism extend and withdraw their membranous wings. It is very curious to see them prepare themselves for flight, by thrusting out, and then unfolding their wings; and again withdraw those joints, and neatly fold in the membranes, to be laid up safe in their elytra or cases; for which service the bones are admirably placed, and the joints ministering thereto are accurately contrived for the most compendious and commodious folding up of the wings.

Mr. Hook hath observed the motion of these filmy wings in some minute spinning flies, which naturally suspend themselves as if pois'd and steady in one place of the air, in which by a faint shadow he could perceive the utmost extremes of the vibrative motion; which shadow, while they endeavour'd to suspend themselves, was not very long; but when they endeavour'd to fly forward, it was something longer; he also fixed the legs of a fly with glew or wax upon the top of the stalk of a feather, and then making it endeavour to fly away, was thereby able to view it in any posture; and found the motion of the extreme limits of the vibrations, to be about the length of the body distant from each other; and concluded by the sound, that
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the wing was moved forwards and backwards with an equal velocity, (and comparing it with a musical string tuned unison to it) the vibrations whereof are so swift, that it is probable there are many hundred, if not thousand vibrations in one second of time, and supposes them the swiftest vibrations in the world; whence he reflects on the quickness of the animal spirits, which serve to supply this motion.

It is observable that most insects are provided with a little ball, [§] or bladder, under each wing, fix'd at the top of a slender stalk, moveable every way at pleasure; in some they stand alone, in others (as in the whole flesh fly tribe) they have little covers, under which they lie and move; with these poises, and secondary lesser wings, they obviate all the vacillations of their body, and poise it in flight, as a rope-dancer ballances himself by his pole loaden at each end with lead.

If one of these be cut off, the creature flies awkwardly for a while, and at last falls to the ground. These bladders being hollow, may serve likewise to produce the noise many sorts of flies make by striking their wings against them; insects that have four wings ballance themselves with the two lesser ones.

The wings of flies are best applied to the microscope between two Muscovy talcs, in an ivory slider.

If with an hair pencil, or point of a penknife, you gently brush or stroke off some of the minute feathers from the wings of butterflies, and some sort of moths, then breathe upon a single talc in one of your sliders, and apply it to the feathers, which seem only like a fine dust, they will immediately adhere to it; if upon their application to the microscope they lie not to your mind, wipe them off, and put on others in the

§ Derham's Phy. Theo. p. 377.

the same manner, till they lie fair for examination, then cover them with another talc, and fasten them down with a ring.

Of a blue fly.

FIG. 86. represents a microscopical picture of this fly; it has many things about it worthy of note; several of which are already described, viz. the head, the eyes, wings, and feet.

The clusters of eyes in this fly are much smaller than that of the drone fly in proportion to its head. Between these two clusters of eyes appeared a scaly prominency B, armed and adorned with black bristles, sharp, and tapering, growing in rows on either side, and bending towards each other, formed a kind of bristly arbor, which almost covered the fore front; at the end of this arch, and about the middle of the face on a rising part C, grew two oblong bodies DD, which through the microscope looked not unlike the pendants of lillies, and appeared to be jointed on two small parts at C, each of which seemed again jointed into the front. Out of the upper part of each of these horns grows a feather, or brushy bristle EE, on the under part of the face FF, were several of the former sort of bended bristles; and below all is the mouth, out of which grew the proboscis GHI; which by means of several joints, the fly was able to move to and fro, and to thrust in and out as it pleased. The end of this hollow body, which was covered over with short hairs, seemed bent at H, and the foremost side of the bended part slit into two chaps^a HI, HI. These he could open and shut very readily, and when he seemed to suck any thing from the surface of a body, he would spread those chaps, and apply the hollow part of them close to it.

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From

^a Hook's Micro. p. 183.

From either side of the proboscis, within the mouth, grow two small horns K K, which were hairy and small in this figure, but of another shape, and bigger in proportion in fig. 83. where they are marked G G, which two are generally called, the antennæ, or horns of insects. Mr. Derham imagines them to be absolutely necessary to the searching out and finding their way¹, as their eyes are immoveable; so that no time is required for their turning them to objects; there is no necessity that the retina, or optick nerve, should occasionally be brought nearer to, or removed farther from the cornea, as it is in other animals; but their cornea and optick nerve being always at the same distance, and fitted only to see distant objects, they would be insensible of, and apt to run their heads against bodies very near them, were they not assisted by their feelers: and that this, rather than wiping the eyes, as some have imagined, is the particular use of the feelers, and is apparent from the flesh fly, and many other insects, which have their antennæ so short and straight, as not to be capable of being bent unto, or extended over the eyes.

The middle part of this fly was cas'd with a firm coat of armour, the upper part of which was thickly beset with conical bristles, pointing backwards; from its under part sprang six legs, three of which are apparent in the figure at M, N, O; they were all of the same structure, being covered with an hairy shell, and composed of eight joints, to the last of which grew the soles and claws before described in pag. 40. From the upper part of the trunk grew the two wings, which are described pag. 45; the hinder part of his body was of a most curious shining blue, and exactly like polished steel, brought to that colour by nealing.

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¹ Derham's Phy. Theo. p. 372.

The lamellated antennæ of some, the cavelated of others, the neatly articulated and the feathered or tufted of others, are exceedingly beautiful when viewed through a microscope.

And in some these antennæ distinguish the sexes *, for in the great kind all those with tufts, feathers, or brush horns, are males; and those with short single shafted antennæ, are females.

Flies of any kind may be examined in the microscope, by sticking them upon the point, or pinching any part of them between the nippers, and so applied to the magnifier under the reflecting concave, if it be opake. And if you are desirous to keep its head, or any other part, it may be stuck with gum water upon a piece of card.

It is very observable, that insects take particular care to deposite their eggs or seed in such places, where they may have a sufficient incubation, and where the young, when hatched, may have the benefit of proper food till they become able to shift for themselves. Those whose food is in the water, lay their eggs in the water; those to whom flesh is a proper food, in flesh; and those to whom the fruits or leaves of vegetables are food, are accordingly repositied, some in this fruit, some in that tree, and some in that plant, and some in another, but constantly the same kind in the same tree, &c.

As for others that require a more constant and greater degree of warmth, they are provided by the parent animal with some place in or about the body of other animals; some in the feathers of birds, some in the hair of beasts, some in the scales of fishes, some in the nose, some in the flesh, nay some in the bowels and inmost recesses of man, and other creatures. And as for others, to whom

* Derham's Phy. Theo. p. 373.

none of these methods are proper, they make them nests by perforation in the earth, in wood, in combs, and the like, carrying in, and sealing up provisions, that serve both for the production of their young, and for their food when produced.

In flies, butterflies, &c. it is observed there is a kind of gluten, by which the female fastens her eggs to the bearing buds of trees, &c. so that the rains cannot wash them off, nor the severest frost hurt them.

Of insects that infest fruit and other trees.

TH E S E insects are of the ichnumon fly tribe; that generated in the plumb, is black, of a middle size, its body near three tenths of an inch long, its tail not much less, consisting of three bristles, wherewith it conveys its eggs into fruit, its antennæ long, slender, recurved; its belly longish, tapering, small towards the thorax, legs reddish, wings membraneous, thin and transparent, in number four.

The blossoms of apples and quinces are infested with multitudes of small animals, so likewise are the green leaves of goose-berry, currant, cherry, grape, plumb, and other trees, overstocked with infinite numbers of these minute flies. Some blackish, others green, some winged, others without wings; several of which bring forth their young alive and perfect; for if their bodies be opened, several imperfect embryo's may be found therein. Also insects of a greenish colour of the shape of fig. 88. but no bigger than a grain of sand when first hatched, which at full growth appear to the naked eye of the size of fig. 89.

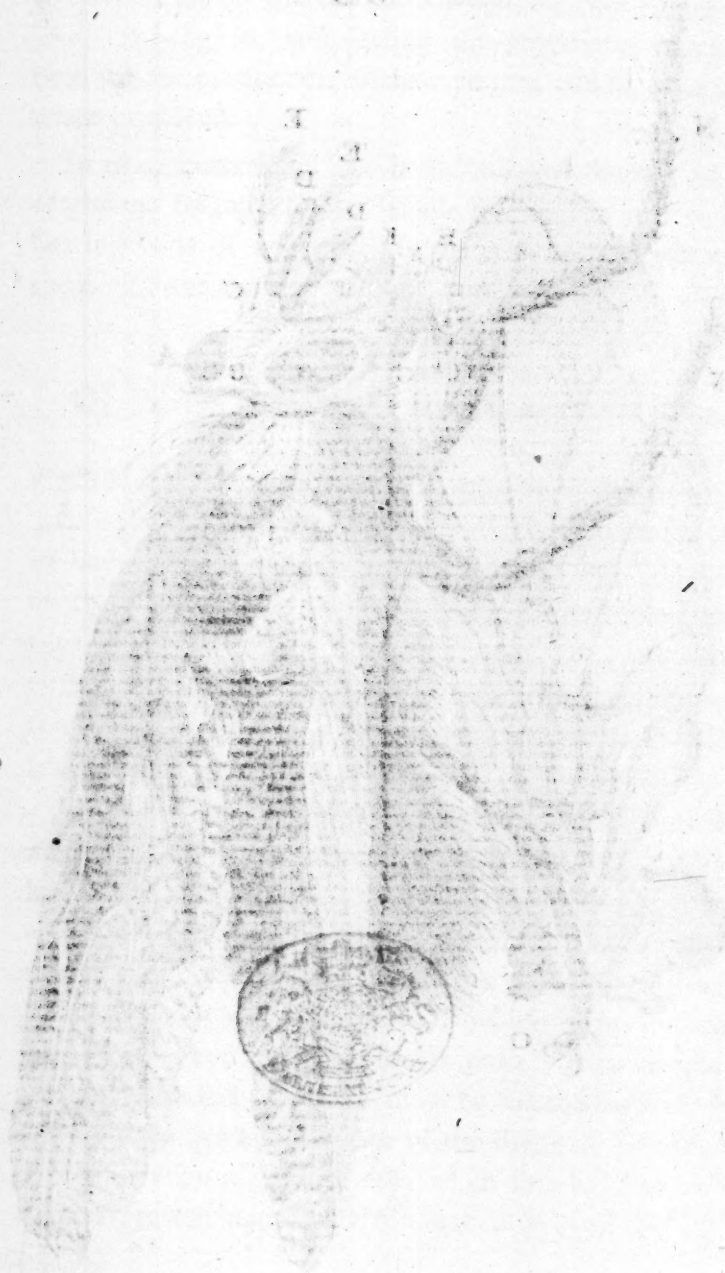
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These little insects Leeuwenhoek calls *pediculus*¹, or louse, who on plucking a leaf from a plumb-tree, and putting it into such a glass tube as has been already described, which he applied to his microscope, and found thereon 36 black flies, and several hundred of these green lice, and among them many which were but just hatched. In a short time these green lice died, and from their carcase came forth a black fly. Fig. 88. represents the carcase of one of the green lice as it appeared before the microscope. The shell or skin of its back had several rows of knobs upon it; its eyes A B were like those of other flies; C D shew its two antennæ articulated and set with hairs. E F G H I K shew the legs, having at their extremity two hooked nails, and short hairs. L M represents the aperture, from whence came out the worm, from which the fly was produced, having first eaten up all the inside of the body of the green louse.

Fig. 90. exhibits one of the minute black flies thus produced from a worm, which had increased itself by destroying its foster parent, and then changed into a nymph, and at last from that to a fly, furnished with all those minute organs as are expressed in the figure; whereof A B shews its two eyes, C D its antennæ, which afford a pleasant sight in the microscope, its curious joints being finely beset with hairs.

E F are two organs, through which it sucks its nourishment, its long tail G H I, K L M N, its four wings bedecked with exceeding fine hairs and a much finer membrane, O O O O O O its six feet, which were also furnished with many joints, and thickly set with hairs. The letters P Q R express the point of the nippers which held the fly before the microscope. These lice are also to

¹ Arc. Nat. Ep. 135.

be found upon the leaves of filberd-trees, with this difference, the former being green, and the latter white.

Upon the leaves of apples and other trees, are found a curious fly ^m, the exquisite make and form of its parts are not to be discerned without a microscope. Fig. 91. represents the size and shape it appears of to the naked eye, and fig. 92. a part of its head, whereof A B are its two protuberant eyes, C D E its snout, furnished with various forceps or teeth, with which it perforates the buds of fruit and flowers; this snout is flexible and capable of bending every way, C F and D G are the two horns which adorn the snout. Fig. 93. is almost a fourth part of the leg of this fly, which consists of four joints. H I are two nails which appear in the microscope, as horn does to the naked eye, and K L shews its two skinny palms or soles.

There is another sort of animalcula found in the wrinkles and wreathed curls of blighted leaves ⁿ, and in the extremity of the sprouts of leaves, as in garden currants, cherries, peaches, nectarines, &c. may be found great swarms of these minute insects, no bigger than an half-grown louse, one of which is represented by fig. 94. of its full growth, and of the size it appeared of to the naked eye. Fig. 95. shews the same magnified and near its last change, the folded wing just beginning to appear at A B. It had six small jointed feet, fenced with short hairs, and two nails on each; C shews one of its eyes, which was of a surprizing make. D F represents the proboscis, with which it perforates the leaves and buds of trees, and then thrusts out its Dart E and sucks their juice. From its tail proceeds two upright parts G H, out of which a transparent liquor is frequently diffused

^m Leeuwenhoek Ex. & Con. Epist. 89.
Ex. & Con. Epist. 90.

ⁿ Leeuwenhoek

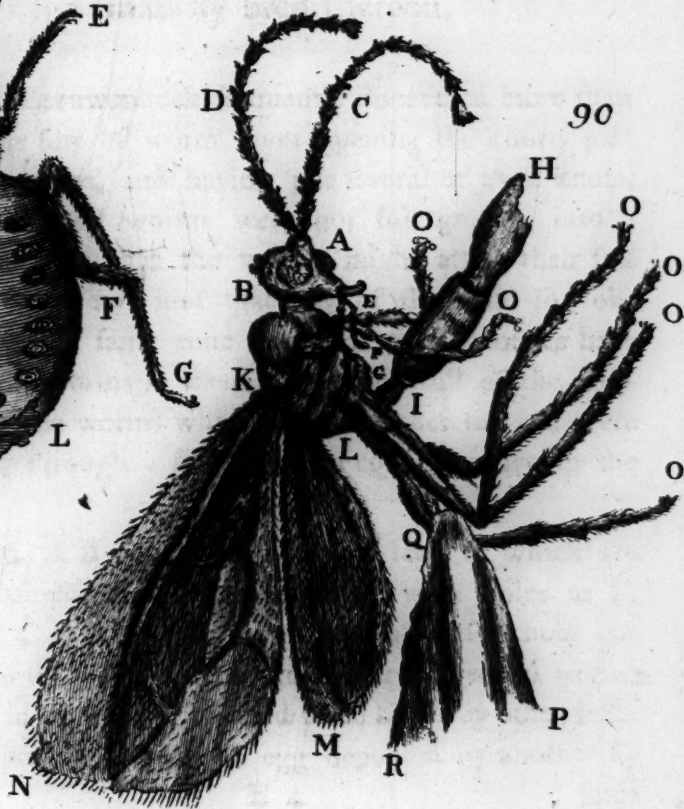
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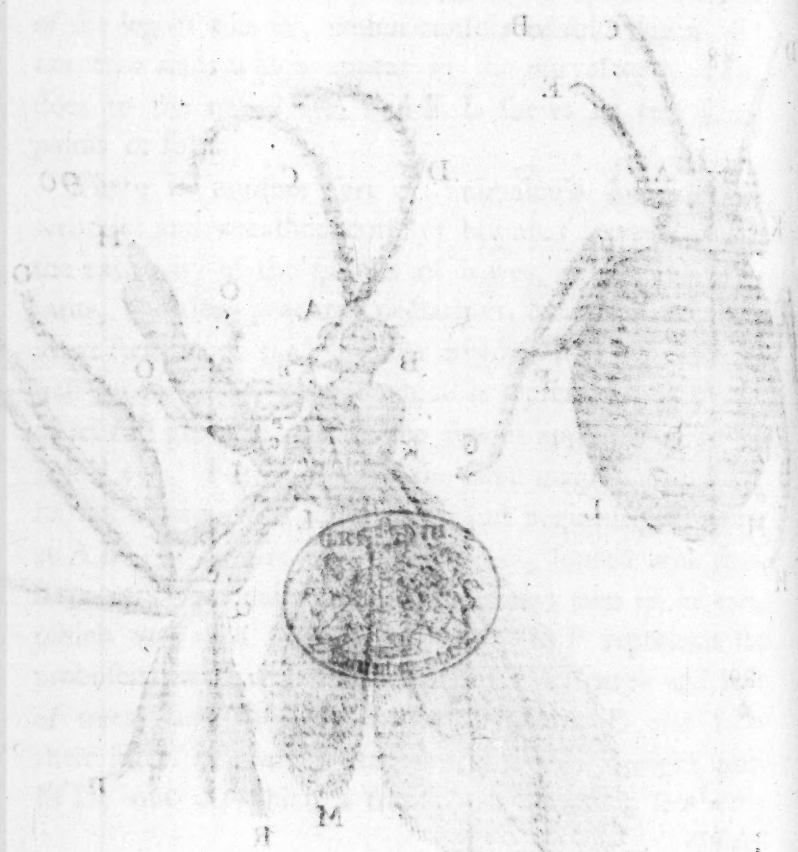
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diffused as at H. I K L is the needle's point, upon which the animal was stuck; and fig. 94, as before hinted, the same animal when changed into a fly.

Mr. Derham could never observe any other kind of fly but the lesser phalenæ * about four tenths of an inch long, to be bred in pears and apples; it is whitish underneath, greyish brown above, spotted about one third with waves of a gold colour, its head small, a tuft of whitish brown on its forehead, and antennæ smooth. The aurelia of this moth is small, and of a yellowish brown.

Of excrescencies growing on willow-leaves, and a small fly bred thereon.

MR. Leeuwenhoek frequently discovered more than one sort of worm upon opening the knotty part of willow-leaves, and having put several of these knots, whose contained worms were not full grown, into a large glass tube, that the worms might attain their full growth, could not find that any of them did so; observing at the same time several of these knots to have none of the worms in them, but almost full of the ecrements of the worms which had been therein, and were dislodged, through a small hole he could perceive in the knots.

Fig. 96. A B represents a willow-leaf, in which are several excrescencies, some of them with holes as F, others as C D E; G H shews two of these knobs cut open, and the posture of the worm therein, several worms lay dead in the knobs supposed to be killed by other lesser worms, produced from an egg deposited by another fly

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since the production of the former, which devoured and lived upon the larger worm.

In the middle of July Mr. Leeuwenhoek cropt several willow-leaves, in which were such like knobs^p, and discovered several worms nearly arrived to their full growth: after these knobs had been in the glass tubes about eight days, upon opening one of them he found, that the worm was turned into a tonnekin or aurelia, and in some others thirteen or fourteen more of the same. In some of the knobs he found the small devouring worms above-mentioned, being so far advanced in growth that they were ready to be changed into flying insects; he put these also in glass tubes. After some weeks certain black flies proceeded from those tonnekins, their hinder parts of an oblong figure, and fashioned like a hook. He also saw two of these small worms (which devoured the large ones) endeavouring to enclose themselves in a web; but by reason of the large space in which they lay, could not bring it quite round them, having made it only on one side, and their change happened in so short a time that he could not make his remarks thereon.

Fig. 97. represents the aforesaid fly as it appears to the naked eye. A B shews the long, slender, and hooked part; on examining this little instrument in the microscope, it appeared to be hollow, and was covered with a great number of fine hairs, as in fig. 98. and on endeavouring to split it, the dart, fig. 99. appeared, whose point is only jagged with saw-like teeth, which being also split, two other distinct hooks^q were taken out of it both of the same shape, a small part of one of them is represented by fig. 100. each of them being fortified with saw-like teeth, and the dart fig. 101, was found to be only a second case or sheath for the two hooks, wherein
the

^p Phil. Transf. No. 269.

^q Arc. Nat. Epist. 136.

the hollownefs does plainly appear, which is filled with a corrofive water. The fly makes ufe of this auger to prepare a convenient lodgment for her eggs (and choofes thofe leaves that are moft lacteous and juicy) under the fkin of the leaf, from whence the worm upon gnawing the veffels for its fuffenance, occafions the fap to flow out of them and to coagulate into that knotty fubftance. Mr. Leeuwenhoek took a fmall devouring worm from a larger that lay dead by it, and put it upon a living one to which it immediately faftened, whilft the other at the fame time ufed all means, by bending, fretching, contracting, and winding its body, to free itfelf from this troublefome gueft, but in vain, the fmall one ftill keeping its hold.

Fig. 102. exhibits a tonnekin, which was a worm but the foregoing evening, and had caft off a very thin fkin; this alfo confifted of feveral rings and circles as when in the worm ftate. The feet and joints thereof were very vifible; A B and A C reprefents its two antennæ; and although they were inclofed in a thin membrane, yet all the joints-might be clearly feen. The change of this worm was fo fudden, that Mr. Leeuwenhoek was never able to fee it.

Not only the willows and other trees, but plants alfo have cafes produced on their leaves, as nettles, ground ivy, &c. by the injection of the eggs of an ichneumon fly. Thefe cafes are generally obferved to grow near to fome rib of the leaf, and their-production thus. The parent infect with its ftiff fetaceous tail, terebrates the rib of the leaf when tender, and makes way for its egg, into the very pith or heart thereof, and probably lays in therewith fome proper juice of its own body to pervert the regular vegetation of it. From this wound arifes a fmall excrefcence which (when the egg is hatched into a maggot)

maggot) grows bigger and bigger, as the maggot increases, swelling on each side the leaf between the two membranes; and extending itself into the parenchymous part thereof, until it grows as big as two grains of wheat: in this case lies a very small white rough maggot, which turns into a beautiful green small ichneumon fly.

Of the crane-fly, or father long-legs.

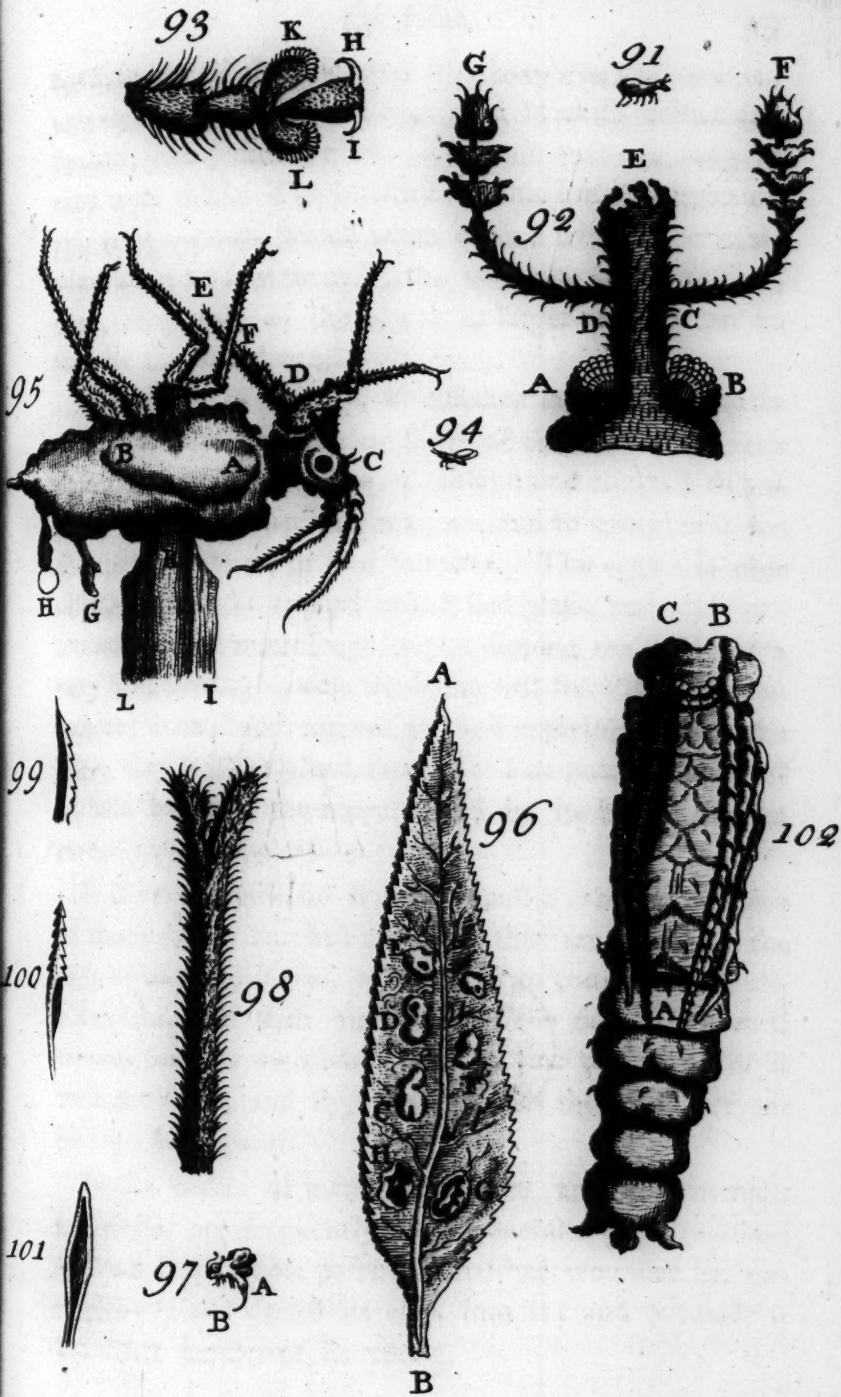
THIS little creature, though but seldom taken notice of, affords an agreeable variety of subjects, when examined by the microscope. It is produced from a worm hatched in an egg, deposited by its parent under the grass in meadows.

These worms are to be met with but in the hot weather upon the ground under the grass in the meadows and fields. Fig. 103. represents one of them, which could not be discerned to change or increase between the months of May and August^r. Fig. 104. shews the worm changed into a nymph, and at its first coming forth greatly agitated, Fig. 105. shews the cast-off skin, which in its change the worm forsook, after which it took wing and flew away in the form of fig. 106. which represents one of these male flies, as does fig. 107. also shew the female.

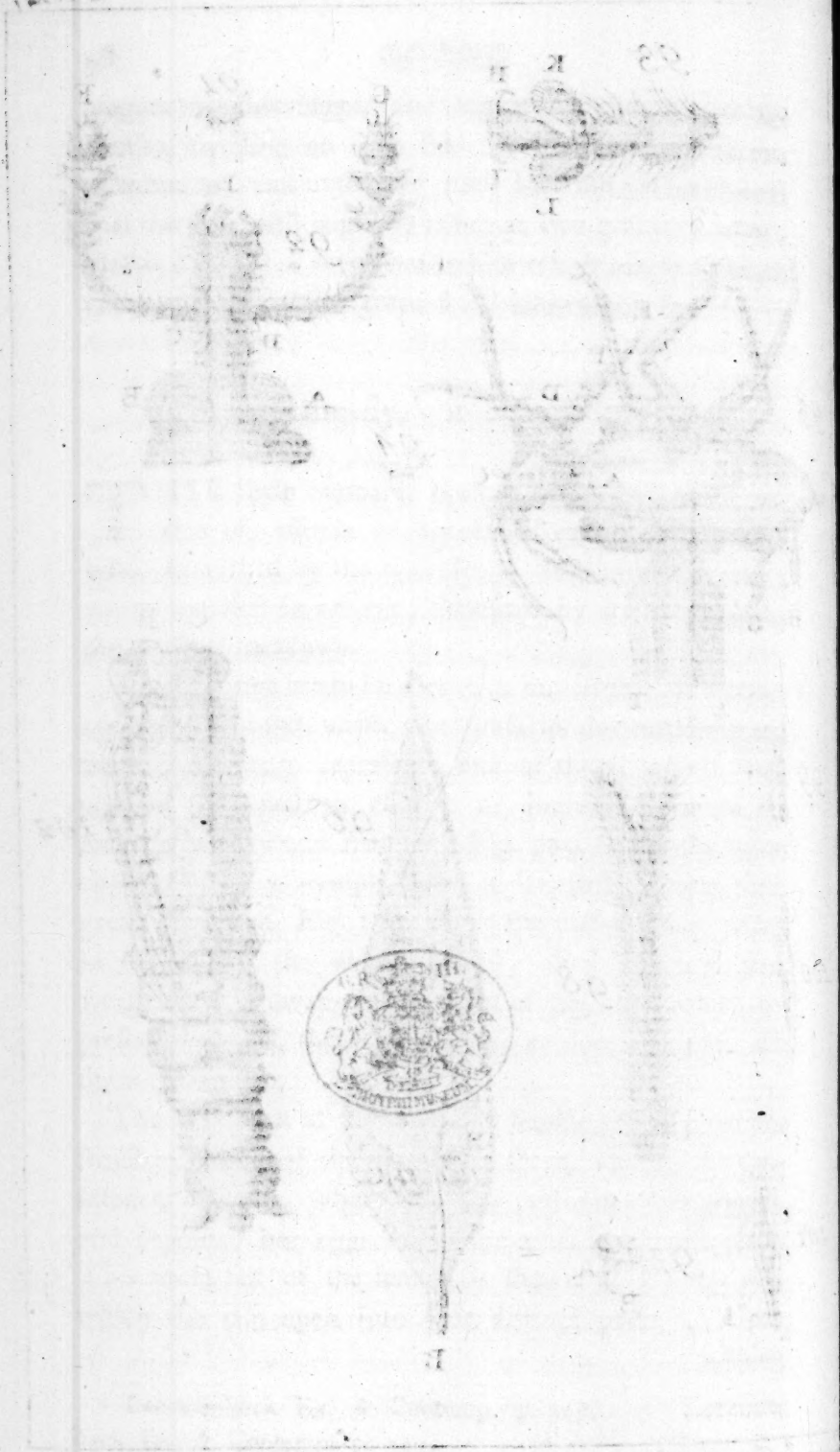
The tails both of the male and female are of a curious structure, that of the female is sharp, and of the consistence of bone, wherewith she perforates the ground, and deposits her eggs under the grass in a moist place. This acute tail of the female is shewn at N, fig. 107. which she can open into four distinct parts^s. Upon opening

^r Leeuwenhoek Ex. & Contemp. p. 347.
hoek Ex. & Contemp. p. 349.

^s Leeuwen-



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opening one of these females Mr. Leeuwenhoek counted upwards of two hundred eggs of a blackish colour and smooth, like polished glass, and about twice as long as they were thick. The intestines of this little creature are also very curious, which when opened with unspeakable admiration he saw them by the assistance of the microscope, as plainly as the bowels in larger animals can be seen by the naked eye.

In the feet of this fly, if dissected in a drop of water upon a hollow glass slip or slider of the microscope, the fleshy fibres may be seen to distend and contract themselves in a most surprising manner, and to continue so for the space of three or four minutes. The eggs also after dissection may be applied to the said glass, and easily examined by the microscope, or on dipping the point of a very fine sewing needle (it being first fixed in a wooden handle) into some turpentine, and applying that to the eggs, they will be glued thereto. The needle itself must be held between the nippers, and by its handle may be turned round at pleasure.

It is very wonderful how so small a creature as some of those newly hatched maggots, that are found in the ends of blighted leaves, can be able to convolve the stubborn leaf, and then bind it with the thread or web it weaves from its own body, also to line the inside of it with the same, and stop the two ends thereof to prevent its own falling out,

In the bodies of many caterpillars, and other nymphs of insects, are frequently found generated great numbers of small flies, whose parent animal had wounded the caterpillar¹, and darted its eggs into it; and so made it the foster mother of its young,

Some

¹ Phy. Theo. p. 390.

Some insects lay up their eggs in clusters, as in holes of flesh, and such places, where it is necessary they should be crowded together, which without doubt contributes towards the hatching ^u.

Other insects observe great order in the disposition of their eggs, which may be found upon the posts and sides of windows, very neatly laid, being round and resembling small pearl, which eggs produce a small hairy caterpillar ^x. The white butterfly also lays its eggs on cabbage-leaves, and always glues one certain end of them to the leaf. If these eggs be applied to the microscope, you will find them curiously furrowed and handsomely adorned.

The pease ichneumon fly ^y is very small, its wings large, reaching beyond the podex; antennæ long, alvæ short, shaped like an heart, with the point towards the anus; it walks and flies but slowly. No tail appears, but they have one concealed under the belly.

Ichneumon properly signifies the Egyptian rat ^z, which has its name from its hunting or tracing out the eggs of crocodiles and asps: a like observation made by some of the ancients on certain insects of the wasp-kind, occasioned the application of that name to wasps, as well as the Egyptian rat; there is but one passage in all antiquity concerning these wasps, viz. in Aristot. de Hist. Anim. Lib. 5. c. 20. which Pliny, Lib. 11. c. 21. hath rendered thus, “Vespæ Ichneumones vocantur (sunt autem minores quam aliæ) unum genus ex aranes perimunt, phalangium appellatum, & in nidos suos ferunt, deinde illinunt, & ex iis, incubando, suum genus procreant;” that is, the wasp, called ichneumons, and which are smaller than other wasps, kill a species of spiders, called phalangium,

^u Phy. Theo. p. 393. ^x Phy. Theo. p. 393. ^y Phy. Theo. p. 387. ^z Phil. Transf. No. 77.

langium, and carry them to their nests, after which they besmear them, and by incubation produce their own species out of them.

There is also a certain black and curious fly, which proceeds from the gouty excrescencies of the briar stalk^a, with red legs. Black, smooth jointed antennæ, large thorax, and belly in the shape of an heart. It leaps like a flea.

The excrescencies of the roots of cabbages, turneps, and divers other plants, have always a maggot in them, not yet sufficiently observed.

Caterpillars, and divers others insects, can emit threads or webs for their use. In this their nymph state, they secure themselves from falling, by letting themselves down from the boughs of trees, and other high places, with one of these threads, and secure themselves in their aurelia state, in cases of their own weaving.

Some of the fly tribe are also endowed with this textile art, of these one sort spins a long milk white silken web as big as the top of one's finger, woven round bent stalks of ribwort, &c. in meadows. The other is a lump of many yellow silken cases sticking confusedly together on posts, under coleworts, &c. these webs contain in them small whitish maggots, which turn to a small black ichneumon fly, with long capillary antennæ, tan-colour'd legs, long wings, reaching beyond their body with a black spot near the middle, the alvus like an heart, and in some a small setaceous tail. Some of these flies are of a beautiful shining green colour. The flies coming from these two productions are nearly alike.

Many of the ichneumon wasps^b are remarkable for the nidification and provision of their young. Those which commonly have golden and black rings round their

^a Phy. Theo. p. 250.

^b Ibid. p. 228.

their alvi, line the cells they perforate in the earth, lay their eggs therein, and then carry into them maggots from the leaves of trees, and seal them up close and neatly; these wasps have their jaws not only very strong, but nicely sized, curved, and set for gnawing, and scraping. Those little holes they perforate in the earth and wood, as well as the several parts of the wasp itself, are a pleasant object for the microscope.

The bearers of fruit-trees are full of asperities, and not so smooth on their bark as the other parts of the tree are. If after harvest, and any time in winter, you view these bearers in the microscope, their cavities will be found to be full of eggs, of an oblong figure, and citron colour, especially in those years wherein the caterpillars have been numerous. Out of these they are hatched in the spring. The seasons which usually destroy them, are such as come in with early heats, before the coming out of the buds and blossoms, and on which a ripping frosty air ensues, which soon kills them.

Of oak cones.

THES E cones are, to appearance, perfectly like gems, only bigger, being nothing else than these increased in bigness, instead of length. The cause of this obstruction in the vegetation is this; into the very heart of the young tender gem or bud, (which begins to be turgid in June, and to shoot forwards the latter end of that month, and the beginning of the next) into this bud the parent insect thrusts one or more eggs, and perhaps not without some venomous ^a ichon therewith; this egg soon becomes a maggot, and eats itself a little cell in
the

^z Phil. Trans. No. 237.

^a Phys. Theo. p. 397.

the very heart or pith of the gem, which is the rudiment of the branch, together with its leaves and fruit. The branch being thus destroyed, or at least its vegetation obstructed, the sap that was to nourish it is diverted to the remaining parts of the bud, which are only the scaly integuments, by this means growing large and flourishing, becomes a covering to the insect case, as before they were to the tender branch and its appendage.

The case lying within this cone, is at first but small, as the maggot included in it is, but by degrees, as the maggot increaseth, it also grows bigger, to the size of a small pea, long and round, in the shape of a long acron.

The insect produced from the cones, hath four membranous wings, reaching a little beyond the belly, articulated horns, large thorax, belly short and conical, legs partly whitish, partly black, of a beautiful shining green, in some tending to a dark copper colour.

The Aleppo galls, wherewith we make ink, are no other than cases in which insects breed, which when they come to maturity, gnaw their way out of them, which occasions those little holes observable in them.

Of this sort also are the little smooth cases, about the size of large pepper corns, which grow close to the ribs, under oaken leaves, at first of a blushing red, afterwards growing brown, hollow within, but an hard thin shell without, in which commonly lies a rough white maggot, afterwards transformed into a black ichneumon fly, that eats a little hole in the side of the gall, and so gets out.

Some of these balls are tender, as those of a yellowish green colour with a reddish cast, about the size of a small musket

* See Phil. Transf. No. 245.

musket bullet, growing close to the ribs, under oaken leaves, their skin smooth with frequent risings therein; inwardly they are very soft and spongy; and in the very center is a case with a white maggot therein, which becomes an ichneumon fly ^f. This gall is remarkable for the fly lying therein all the winter in its infantile state, and comes not to its maturity till the following spring. In autumn and winter those balls fall down with their leaves to the ground, in which the inclosed insect is fenced against the winter frosts, partly by other leaves falling pretty thick upon them, and especially by parenchymous spongy walls, afforded by the galls themselves.

From the large oak balls, called oak apples, which grow in the place of the buds, out of these galls come another species of black flies.

The gouty excrescencies in the body, and branches of the black-berry bush, produce a small shining black ichneumon fly, about a tenth of an inch long, with red jointed horns, four wings, red legs, and a short belly. They hop like fleas.

All these insects afford an entertaining and agreeable variety when viewed through a microscope.

^f Phy. Theo. p. 400.

MR. Leeuwenhoek discovered upon the leaves of some white nutmegs, an animalcula or minute worm, which appeared to the naked eye of the size of fig. 108. but is represented in fig. 109. as it appeared when placed before the microscope. Its body was jointed in several places, and thickly set with hairs; it had six short feet, which end with a shining nail, toothed like a saw, as at A, B, C, D; the hinder part of its body was very full of blood vessels, as appears at E, F, G, H. At I K are two shining horns jointed and beset with hairs. At L are represented its forceps, with which the worm eats its way into leaves or wood, &c. M N shew the two lesser horns which adorn the head of the worm. This worm after some little time was changed into a flying insect, as exhibited in fig. 110. whereof L M, B N, are its two horns, which consisted of divers joints and hairs, B L its eyes furnished with a number of little lenses, as the eye of the drone fly before described. It had also six feet armed with talons, as before shewn: these legs had several joints, and were covered with bristles or thorns; two of these feet and nails are shewn by the letters C O, D P. D E, and K I represents the two cases or shields under which the wings are folded. These cases are most curiously adorned with strait rows of rings throughout their whole length. The hinder part of its body is jointed as it were with hollow notches, much after the same manner as the worm from which it was produced. If the wing be considered, it will be found to consist of several small vessels or nerves

that assist in the expansion thereof. The exquisite neatness with which this minute wing was folded under the shields, is surprizingly beautiful, as appears between G H. With what wonderful nerves must these minute wings be strengthened, that can enable this insect so readily to fold up the extremity of this filmy membrane in so neat a manner, and to expand it again, as it were instantaneously, whenever it is inclined to fly? That the curious folding of these sort of wings might be comprehended, Mr. Leeuwenhoek took off one of the shelly cases and placed the wing before the microscope, which appeared as in fig. 111. Q S T V W X Y represent the wing as it lay covered under its shield. It was broadest about V; the second wing, which I suppose to be its ballance or poize, is shewn at S T. The extremity W X Y, shews those neat foldings before spoken of, which, together with the strength of the nerves, discover the Almighty's wisdom in their contrivance.

I have found these insect flies in summer-time flying about my workshop, and have observed them to answer all the above description. They are so small, that I have applied them to the microscope in the ivory sliders, but they are better seen when applied in the nippers.

There is likewise a small scarab in the very tips of elm-leaves *. In the summer many of these leaves may be observed to be dry and withered, and also turgid, in which lies a dirty, whitish, rough maggot, from which proceeds a beetle of the smallest kind, of a weefel-colour; it leaps like a grasshopper, although its legs are but short, black eyes, vaginæ thin, and prettily furrowed, with several cavities, small dubbed antennæ, and a long proboscis.

The

The same, or one much like this is found on the tips of oak and holly leaves.

The horse-fly is also a curious object; its eye is in the form of other flies, but is as it were indented all over with a pure emerald green, its body like silver in frost-work^b, fringed all over with white silk. If the head of this fly be cut off just at the setting on of the neck, a pulsing particle may be seen beating through the skin for half an hour together.

The trunk or proboscis of a butterfly, which lies wound up like an helix or spiral spring, gradually growing slender as at fig. 113, supplies the office both of mouth and tongue, it may with a pin be easily drawn out to its full length, if it be cut off and laid upon the object carrying glass, and so applied to the microscope you will see it wind and coilⁱ itself up, and then to open itself again for a long time together, nature having made it of a sufficient length, that when extended it may reach into the hollows of flowers, and from thence extract their dews and juices. It consists of two tubes near its extremity, as represented at A C, fig. 113. the cavities of which unite at D, and from thence to the throat of the butterfly form but one channel^k. These tubular extremities are unfolded in the manner expressed at B T N, fig. 114. in order to extract the dews, &c. from flowers; after which it is immediately drawn back and coiled up into an helix. M M, fig. 115. represents one of the extreme parts viewed with a greater magnifier, and delineated exactly in the manner as it is applied to leaves and flowers. Whence it appears, that it is not the extreme end of the proboscis, which extracts the dews and juices;

F 2

but

^b Power's Micro. Obs. p. 7.
de Bonan. Pars 2. p. 48.

ⁱ Ibid. p. 8.

^k Micro.

but several nipples D E F, that are applied to the leaf A C, at the points i i i.

In all grasshoppers there is a green film or plate (like a croslet) which covers the neck and shoulders; if you raise it up with a pin you may see their heart beat ¹ for a long time together. The grasshopper is best held between the nippers, and so applied to the magnifier.

There is a pretty object, which is a white oblong insect that sticks to the back-side of rose-tree leaves ^m in August, of a perfect white, it changes into a small yellow locust, with two white wings longer than its body, and two pointers in the snout like a pair of closed compasses, and may be plainly seen when the fly is laid upon its back.

Upon the backside of the leaves of gooseberries, sweet briar, and golden mouse-ear in April and the beginning of May, is a greenish grasshopper or locust ⁿ, which is a pleasant object; when placed before the microscope it hath two horns and four legs, and two curious black eyes.

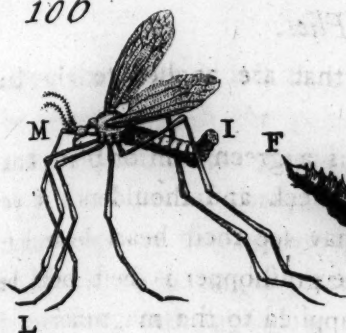
On sycamore leaves there is a yellow insect ^o, which at first hath no wings, but six legs and two horns which are slit; it runs nimbly, the eyes are globular and red, pearled and prominent; near the shoulders are two stumps, whence two long wings come forth, when it changes into a fly or locust, it consists of annular circles, and is hairy towards the tail.

There is to be found a small long black insect, creeping and leaping amongst pinks, gilly-flowers, rose-leaves, &c. with a wasp-like body, with six or seven annular divisions; two curious horns arising from a black knobbed root, two fine long yellow wings, black eyes, and six black legs, they are killed with the least touch imaginable;

¹ Power's Micro. p. 24. ^m Ibid. p. 27. ⁿ Ibid. p. 26.

^o Ibid. Micro. Obs. p. 32.

106



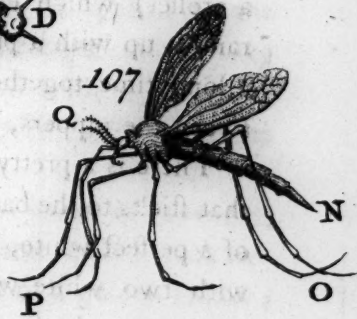
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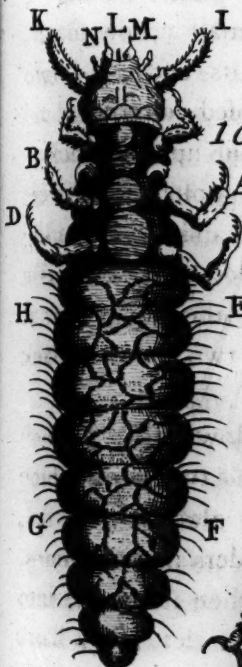
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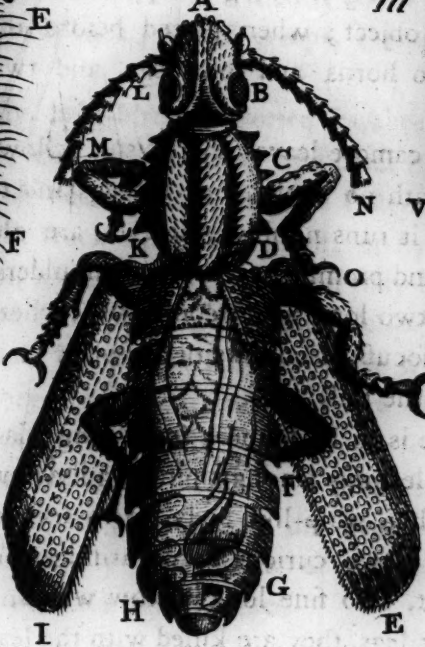
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able; their size is less than that of a louse ^p: they may be taken up with the point of a pin dipped in spittle, and by that means placed, or as it were glewed to a very small bit of card, which may be applied to the microscope in the nippers. And stronger insects may be stuck to a larger piece of card with a touch of turpentine, and applied to the magnifier in the nippers as before.

On the froth, which hangs on the leaves of lavender, horse-mint, rosemary, &c. ^q (by some called cuckow-spit) is always found a little insect of a golden colour; it hath six legs, with two black claws at the end of each, which it can open and shut at pleasure; its eyes are pearly and of a dusky red, a long reddish proboscis is situated between its fore legs; its tail had several annular divisions that ended in a stump, which it could at pleasure thrust out or draw back; it first creeps, then leaps, and at last flies.

The cow-lady, lady-bird, or spotted scarabee, is a very nimble animal; cut off its head, and erect it perpendicularly upon the neck (which may be fastened to a bit of soft wax first stuck upon the point, or by a drop of gum-water upon a piece of card, which may be held in the nippers, and so applied to the microscope) and you will see two small black eyes set upon three white plates like polished ivory, two small ones on one side, and a large one on the other; pull off both the crustaceous and filmy wings, which are a fence to a thin tender black skin, under which the pulsation of the heart ^r may be seen to beat vigorously for twelve or fourteen hours, after the head and neck are separated.

F 3

There

^p Power's p. 31.^q Ibid. p. 28.^r Ibid. p. 30.

There is a fly with grey and black streaks on the shoulders *, and chequered on the tail with the same colours; upon opening the female of this fly, which may be distinguished by a redness on the extremity of the tail, you will find two bags of live white worms, long and round in shape, with black heads, moving both on the hand and in the unopened vesicles backwards and forwards, being disposed in cells according to the length of the animal's body.

Of the cochineal fly.

THE microscope hath discovered to us that cochineal, so valuable for its use in dying crimson, scarlet, and purple, is an insect bred upon the plant called prickly pear, or Indian fig †; and upon the leaves or twigs thereof are small knobs or protuberances, which produce little worms that in time become flies, resembling cow-ladies, or lady-birds; which, when arrived at their full growth, are taken by the inhabitants (of the islands of Cuba, Hispaniola and Jamaica, from whence it most commonly comes) and exposed to the heat of the sun to dry, and rubbed between the hands till their wings, legs, &c. fall off. Upon steeping some of the grains of cochineal twenty-four hours in water, a trunk with scales and legs will appear; and if their bodies be opened, many eggs of different sizes may be also found.

Fig. 116. represents a grain of cochineal; fig. 117. another grain, as it appeared through a microscope, in which at the extreme parts C and E F, an orifice appears, from whence the string was broken off, whereby both parts of the body were joined together. The concave
arches

* Phil. Transf. No. 72.

† Phil. Transf. No. 302.

arches D G, &c. are not natural, but adventitious to the same grain, proceeding only from the drying or shrinking up of the great number of eggs that lie within the animalcula; for if the same grain was well soaked in water, the concave parts would become convex. Fig. 118. shews an egg with its membrane, as it was taken out of a grain of cochineal steeped in rain water for about twenty-four hours; in which might be seen the young one, and its shell surrounding it. L M N, fig. 119. represents one of these unborn animalcula. Fig. 120. shews the body of another animalculum which was taken out of the egg-shell, in which not only the body was distinctly seen, but also the parts thereof divided into several circles, and likewise the two horns with the joints wherewith nature hath provided all those unborn animalcula, were plainly visible when placed before the microscope. B H, D I, and D K, shew its four legs, the other two being hid from the sight. F G represent the horns, at the extremity of each of which are three small hairs.

Of the death-watch.

TH E R E are two kind of insects which make a regular clicking noise like the beats of a pocket watch; one of them called by Swammerdam, *scarabeus sonicephalus*, and the other called by Mr. Derham, *pediculus pulsatorius*.

The first of them is a small beetle, about five sixtenths of an inch in length^u, of a dark brown colour, with spots somewhat lighter irregularly placed. It is represented of its natural size at fig. 121. Under its vaginæ are pellucid wings, the head large, by reason of a cap or helmet which covered it, only a little turned up at the ears; under this appeared its head, which was flat and thin, the eyes forward, the lips hard and shining, the bars of the helmet greyish; two antennæ proceeded from under the eyes, the head all hairy, and face thick of curled hair; on the belly was a little hair, but thinly set; its eyes like those of a fly. Fig. 122. is a microscopic picture of it; between the eyes the face rises in a little ridge, which is the nose; and just below it the nostrils are covered with strait pendulous hair, the lip-shades shew the more depressed places; under this lip are four visible forceps, two on each side to lay hold on its food. They make a noise just like the beats of a pocket-watch. Mr. Derham has often caused one of them to beat when he pleased by imitating its beating, and this he kept in a little box about three weeks; and imagines, that these pulsations is the way these insects woo each other, and invite to copulation; and that it always draws back its mouth, and beats with its forehead^x.

The

^u Phil. Transf. No. 245.^x Phil. Transf. No. 271.

The other death-watch is an insect different from the foregoing, that beats only about seven or eight strokes at a time, whereas the former will beat some hours together without intermission, and its strokes slower, and like the beats of a watch. It is a small greyish animal, much resembling a louse; for which reason it is called *pediculus pulsatorius*. It is very nimble, but extremely shy when disturbed; it will beat freely enough before you, and also answer you when you beat, if you can view it without giving it any disturbance, or shaking the place whereon it lies. It is not certain whether they beat on any other thing but paper, their noise being heard only in or near it.

Fig. 123. represents the second sort of death-watch, as it appears to the naked eye. Fig. 124. shews it a little magnified; its shape and colour is not much unlike a louse; it is common in most houses in the warm months, but in the cold season of the year it hides itself in dry obscure places, and is seldom seen; some time after copulation, they lay their eggs in dry dusty places; they are much more minute than the nits of lice, of a whitish colour, and are hatched by the warmth of the approaching spring, which to them is all the same as an incubation: the insect is fully hatched, and can creep about at the beginning of March, or sooner if the weather be warm; at their first quitting the egg-shell, they are so exceeding small, as scarce to be discerned, without the assistance of a convex glass: in this state Mr. Derham could find no other difference between them and mites in cheese, when viewed with a microscope that magnified much, but that mites had more bristles about the breech: in this shape they continue six weeks or two months, feeding on divers things they can meet with; after which they

they gradually increase towards their more perfect state, when they become like the old ones.

Mr. Derham has plainly shewn, that their ticking noise is a wooing act, and that it is commonly about July ²; he never found them in coitu, till about a week or a fortnight after their ticking; though it is probable they copulate at that very time. He has seen the old death-watches feed upon dead insects, as the young ones do, and also upon biskets, tallow, &c. nay dust itself, and hath observed them through a microscope to select some grains thereof, and reject others.

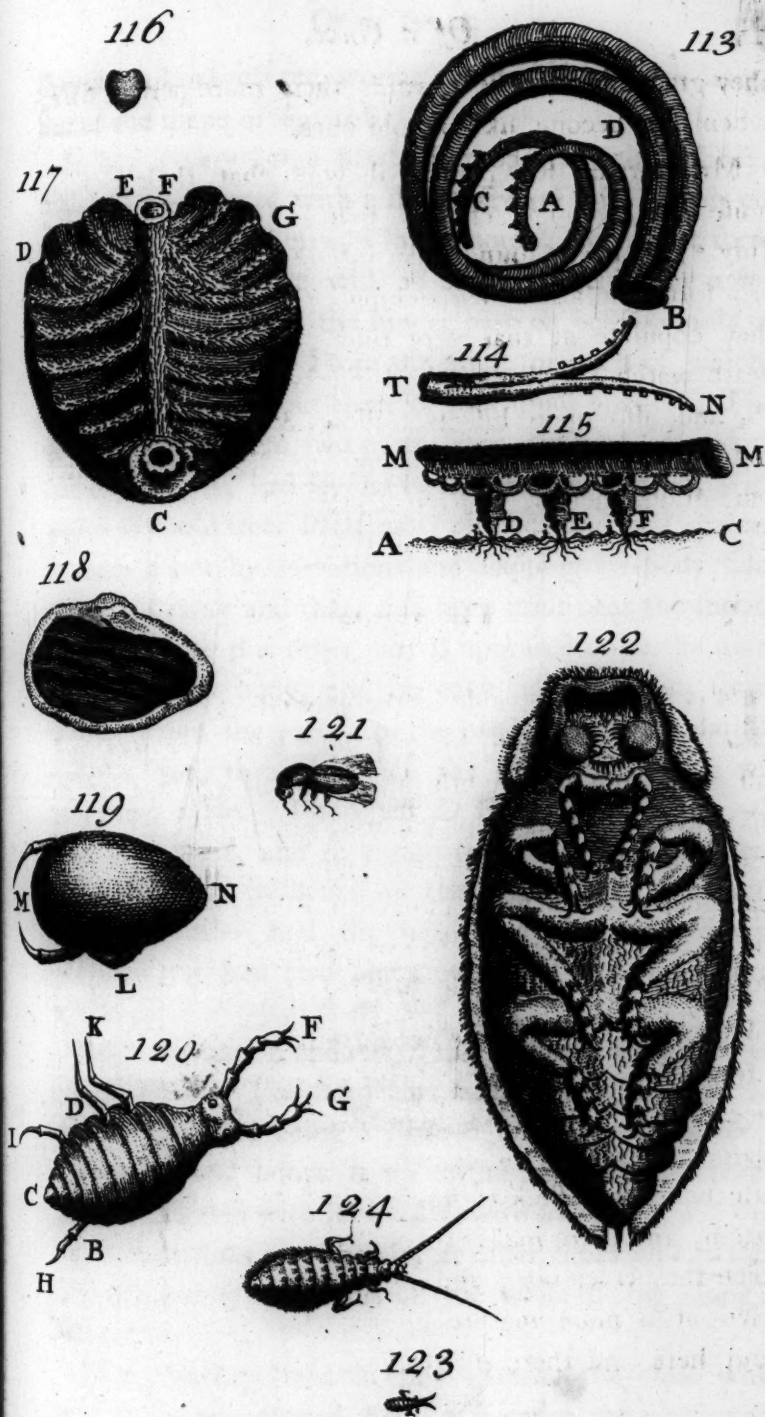
Of a gnat.

THE first observable in the generation of this insect, is its vast spawn, some of them being one inch and half long, and one eighth of an inch broad, floating in the water, but being made fast to something to prevent its being washed away; in this transparent spawn the eggs are neatly deposited, in some a single, in others a double spiral line ², running from end to end, as in fig. 125 and 126. and in some transversely, as in fig. 127.

When the eggs are by the heat of the sun, and warmth of the season, hatched into small maggots, these maggots descend to the bottom; and by means of some of the gelatine matter of the spawn, which they take along with them, they stick to stones, and other bodies at the bottom, and there make themselves little cases or cells, which they creep into, and out of at pleasure, till they arrive at a more mature nymph state, and can swim about here and there in quest of food; at which time they

² Phil. Trans. No. 271.

² Phy. Theo. p. 394.

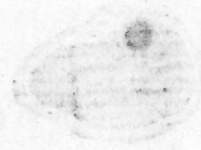
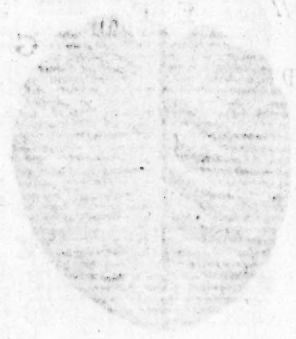


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they are a kind of red worms about half an inch long, but of the shape of fig. 128.

It has a very large head, in proportion to its body, which is all covered with a shell; several tufts of hair on several parts, two horns, a large mouth, &c. The form of the whole creature will be better perceived by a description of fig. 128. the hinder part or belly consists of eight several joints. From the midst of each of which, on either side, issue out three or four small bristles. The tail was divided into two parts, very different in make; one of them A, had several tufts of hair or bristles, with which it could steer itself as it pleased, and was enabled to swim about by curvations and flapping its body sideways, this way and that, and keep itself near the surface of the water: the other part B appeared to be the ninth division of its body, and on each side had many single hairs. From the part C to the head, appeared a darkish coloured gut, through which the peristaltic motion was very discernable. The chest D E of this creature was thick and short, and so transparent, that its white heart could be seen to beat: its chest was stuck with several tufts or bristles, and the head was also adorned with the same; it had two black eyes, and two small horns F G.

Both the motion and rest of this creature are surprizing and pleasant. The tail seems much lighter than the rest of its body; and being a little lighter than the water in which it floats, buoys it up to the top thereof, where it hangs suspended with its head downwards; they lift their heads sometimes into the air, at other times plunge them into the water, their tails all the while sliding along its surface.

After having lived in this manner the time which providence has allotted them, a stranger change succeeds; they



they appear in form of fig. 129. and then they cast off their whole skin, eyes, horns, and tails; and issue forth as insects of a quite different element: the most beautiful and elegant plumage adorns their heads; their limbs are of the finest texture; their wings are curiously fringed and ornamented; their whole bodies are invested with scales and hair; and they are actuated by a surprizing agility; in short, they become gnats, and spring into the air; and what is most amazing, a creature, that but a minute since was an inhabitant of the water, would now be drowned if it were plunged therein.

It is very probable, that many sorts of the animalcules in fluids undergo some such like change.

Of the tufted, brush-horned, or male gnat.

IT S surprizing and particular beauties are only to be discovered by the microscope; and is exactly of the shape of one of those which Mr. Hook observed to be generated out of one of the little watery insects just described.

Nature has adorned it in a most surprizing manner: its head A is exceeding small in proportion to its body, which consists of two clusters of pearled eyes, fig. 130. curiously ranged like those of other flies; between which, upon two blackish balls, are placed two long jointed horns D, tapering towards the top; from whence issued out in a circular manner, multitudes of small stiff hairs from its several joints, exactly resembling the sproutings of the herb horse-tail. There are also two other jointed and bristled horns or feelers D, and a proboscis F, underneath which is the sucker or sting, which in some gnats is very long. This small head, with its appurtenances,

tenances, is joined by a short neck to the thorax G, which is large, and as it were cased with a black shell; out of its under part proceeded six long slender legs H H, &c. much like those of other flies, but longer and slenderer, which are not expressed in the figure, because of their great length. From the upper part proceeds two long slender transparent wings, shaped somewhat like those of a fly; underneath which, as is observable in many sorts of flies, are placed two small bodies, which are its ballances or poises. Its belly large, and extended into nine partitions, each being armed with rings of shells; six of which were so transparent, that the peristaltic motion was plainly visible. A small clear white part at I, seemed to beat like the heart of a larger animal; the three last divisions of the tail were covered with opaque shells.

Of the great bellyed or female gnat.

ALTHOUGH this gnat, as represented in fig. 131. differs from the former in shape, yet this sort also has been found to be generated out of the water insect before described: its wings were larger than those of the other; its belly bigger and shorter; its thorax not much unlike that of the other, having a strong rigid back piece and breast plate; its head larger and neater shaped; the horns, that grew out of those two little balls, which were between its eyes, was of a different shape from the tufts of the other gnat; these having but a few knots or joints and a few short bristles; the foremost horns or feelers like those of the former.

In different species of gnats their wings are also different; some having a border of long feathers, others of short

short ones, and others none at all : the rib-work of the wings is feathered in some and scaled in others, and in some beset with prickles.

Mr. Hook suffered one of these gnats to pierce the skin of his hand, and thence to draw out its fill of blood, which made it appear very red and transparent, and this without any further pain, than whilst the sting was entering ; a good argument that these creatures do not wound the skin out of revenge, but for mere necessity to satisfy their hunger.

This piercer, sting, or sucker, as represented by F G H I, fig. 132. is a case covered with long scales and hairs ; it lies concealed under the gnat's throat, when not made use of ; but when it is, the side G H opens, and four darts are thrust out therefrom occasionally ; one whereof H K (minute as it is) serves for a case to the other three ; the sides of which towards the point K are barbed or indented. F I shew that part of the sting where it was cut off from the gnat's throat.

Fig. 133. represents part of the second sheath, whose sides near the top are barbed, but not here expressed. This also opens side-ways for a passage to the three included stings.

Fig. 134. shews all the parts of the stings wherein two of the interior ones might be seen barbed and indented towards the point ; their fineness is almost inexpressible, they have three sides, as represented in fig. 135, whose edges seemed to join alternately (which when so united resemble a three edged sword, or dagger.) Fig. 136, shews another part of one of those interior stings, which is remarkably small and somewhat curved. Its top on the plain side is shewn at fig. 137. which top is represented in another position, fig. 138. A, and in the position of B its hooks might be seen. When these darts

are

are thrust into the flesh of animals either successively or in conjunction, the blood and humours of the adjacent parts must flow to, and cause a tumour about the wound, whose little orifice being closed up by the compression of the external air can afford them no outlet. When a gnat finds any tender juicy fruits, or liquors, she sucks up what she likes through the outer case, without using the darts at all; but if it is flesh, that resists her efforts, she stings very severely, then sheaths her weapons in their scabbard, and through them sucks up the juices she finds therein. Upon dissection many curious things may be discovered, viz. numberless animalcula in the semen of the male ^b, and in the female a surprizing quantity of eggs.

There is a kind of gnat which lays its eggs frequently in dead beer, &c. and some time after this the maggots are so numerous, that the whole liquor seems to be alive, being full of maggots; the larger sort being the offspring of this gnat ^c; and the smaller that of a small dark coloured fly, tending to a reddish colour, frequent in cellars and such obscure places; they turn to aurelia, and the larger sort from that to a gnat of a brown colour. The chief difference between the male and the female is, that the male is least, hath a slenderer belly, and its podex not so sharp as the female's is. This gnat hath no spear in its mouth.

These insects may be applied to the universal microscope, by pinching them between the nippers, or sticking them upon the point; their stings when cut off may be best examined upon a glass slider when placed on the stage.

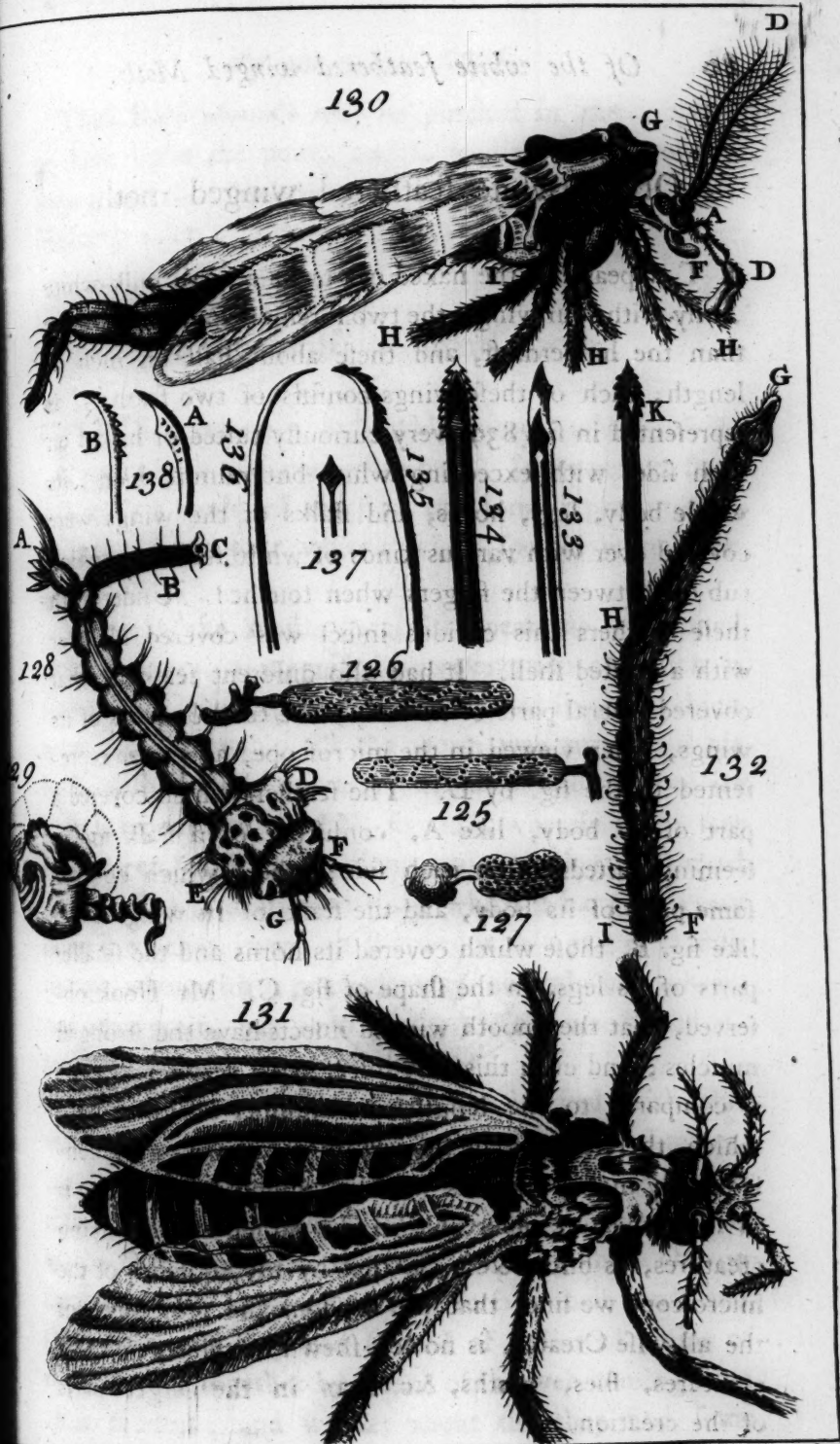
^b Art. Nat. Tom. iv. p. 22.

^c Phy. Theo. p. 386.

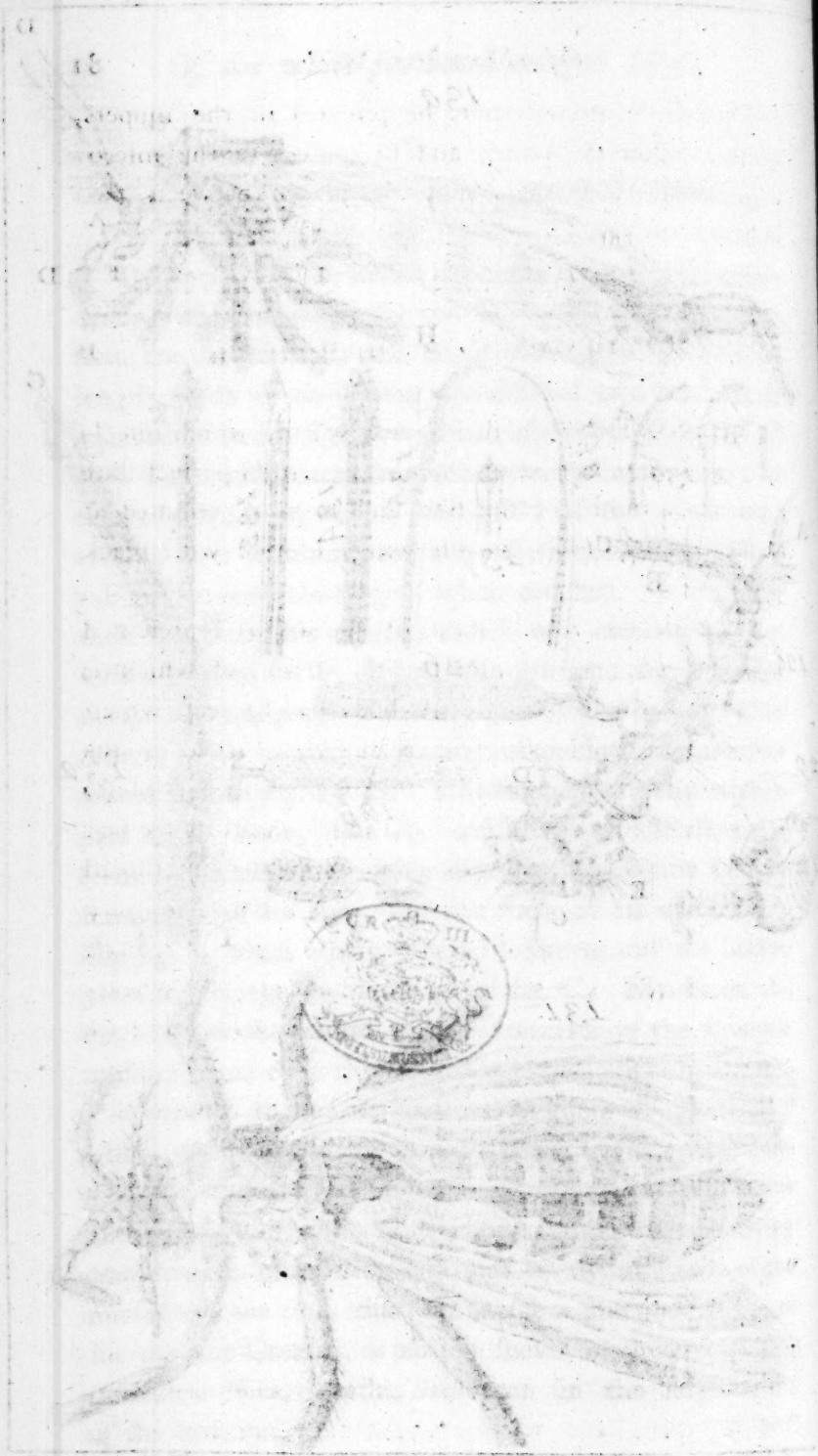
Of the white feathered winged moth.

IT appears to the naked eye to be a small milk-white fly with four wings, the two foremost somewhat longer than the hindmost, and these about half an inch in length; each of these wings consists of two feathers, as represented in fig. 839. very curiously tufted or haired on each side, with exceeding white but minute hairs; its whole body, legs, horns, and stalks of the wings were covered over with various kinds of white feathers, which rub off between the fingers when touched. Underneath these feathers this curious insect was covered all over with a crufted shell. It had also different feathers, that covered several parts of its body; the tufts or hairs of its wings, when viewed in the microscope, appear as represented in the fig. by D. The feathers which covered a part of its body, like A, consisting of a stalk and a seeming tuftedness on each side; others which covered some parts of its body, and the stalk of its wings much like fig. B, those which covered its horns and the smaller parts of its legs, in the shape of fig. C. Mr. Hook observed, that the smooth winged insects have the strongest muscles; and even this very insect had a very small body, if compared to the length and number of his wings; which therefore as he moved them very slowly, consequently moved them as weakly; which last property is in some measure observable in the larger kind of flying creatures, as birds, &c. So that by the assistance of the microscope we find, that the wisdom and providence of the all-wise Creator, is no less shewn in those despicable creatures, flies, moths, &c. than in the larger parts of the creation.

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These little animals may be pinched in the nippers, or stuck upon the point, and so applied to the microscope; and its feathers may be placed between two Muscovy talcs.

Of the wolf, or small moth.

THIS insect is a little white worm, which infects granaries and corn-chambers. In its perfect state it is really a moth, of the size and form represented at fig. 140. it has four whitish wings spotted with black spots.

When in the reptile state, it appears as represented under fig. 141. a magnified representation of which is seen at K L, the fore part of its body had six feet, which were not discernable till the worm was turned on his back, with its belly upwards; in this position part of its body is represented at M N, fig. 146. wherein its six feet may be seen. As it creeps along, an exceeding fine thread or web issues from its mouth, by which it hangs to every thing it touches, its mouth is armed with a pair of reddish forceps, wherewith it gnaws its way, not only into wheat, and other grain, but even perforates into wood, and almost any thing it meets with.

In those corn-chambers that are infested with this vermin, they may be seen near the decline of the summer, crawling up the walls in great numbers, searching out for places where they may abide in safety, during their aurelia state: for when the time of undergoing a change into that state approaches, they forsake their food, and those little cells they had formed of hollowed grains of corn, clotted together by means of the web coming from their mouths; and wander about till they find some

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wooden

wooden beam, or other body to their mind, into which they gnaw holes with their sharp fangs, capable of concealing them; and there envelope themselves in a covering of their own spinning; where they soon become metamorphosed into dark coloured aurelias ^d, and continue so all the winter unactive and harmless: but about April or May, as the weather grows warm, they are transformed into moths of the kind before described. Then are they to be seen in great numbers taking little flights, or creeping along the walls. In the fly-state they eat nothing, therefore are not mischievous, but soon copulate and lay eggs, not larger than a grain of sand, in shape like those of an hen, each female sixty or seventy, which by means of a tube at the end of her tail, represented by fig. 142. as it appears in the microscope, she thrusts or insinuates into the little wrinkles, hollows, or crevices of the corn; where in about sixteen days they hatch, and then the plague begins: for the minute worms or maggots immediately perforate the grain where they are hatched upon, eat out the very heart of it, and with their webs cement other grains thereto, which they likewise scoop out and devour, leaving nothing but husk and dust, and such a quantity of their dung, as shews them to be more voracious insects than the weevil; hereafter to be described.

These worms or maggots may be kept all the winter in glass tubes, that are stopped at each end with a cork and wax, having first a bit of a very small glass capillary tube, put through the cork to give them air. In this manner Mr. Leeuwenhoek confined some of these moths with a few grains of corn, and saw them lay their eggs in the crevices of the corn; also in this manner he observed all the above particulars.

These

^d Leeuwenhoek's Exp. & Contemp. Epist. 71.

These little moths are covered all over with an infinite number of little feathers joined to their wings, and other parts of their bodies by a quill, as those of birds are, but so extremely different in shape, that scarce two of them can be found alike. Fig. 144. shews three of the larger sort, somewhat blackish towards the top, but transparent near the stalk. Fig. 143. shews three others perfectly transparent, ten of the smaller sort are exhibited in fig. 145. but all of them of a different shape. These feathers which compose the borders of the wings, but especially those which grew upon that part of the wing which was near the body of the moth, were also of different fashions, and much longer than the former. Five of this sort are shewn in fig. 146.

The methods of destroying this vermin are, when they forsake their food, and ascend the walls, or when they appear in the moth state; at both these times they may be crushed to death by clapping sacks upon them: but they may still be more effectually destroyed by closing up all the doors and windows, and filling the corn-chambers with the fumes of brimstone *, by leaving it burning on a pan of charcoal, without giving it any vent for twenty-four hours: however, after that great care must be taken to open them all again for some hours, that the fumes may be entirely gone before any body enters.

N. B. The fumes of the sulphur are not hurtful to the grain.

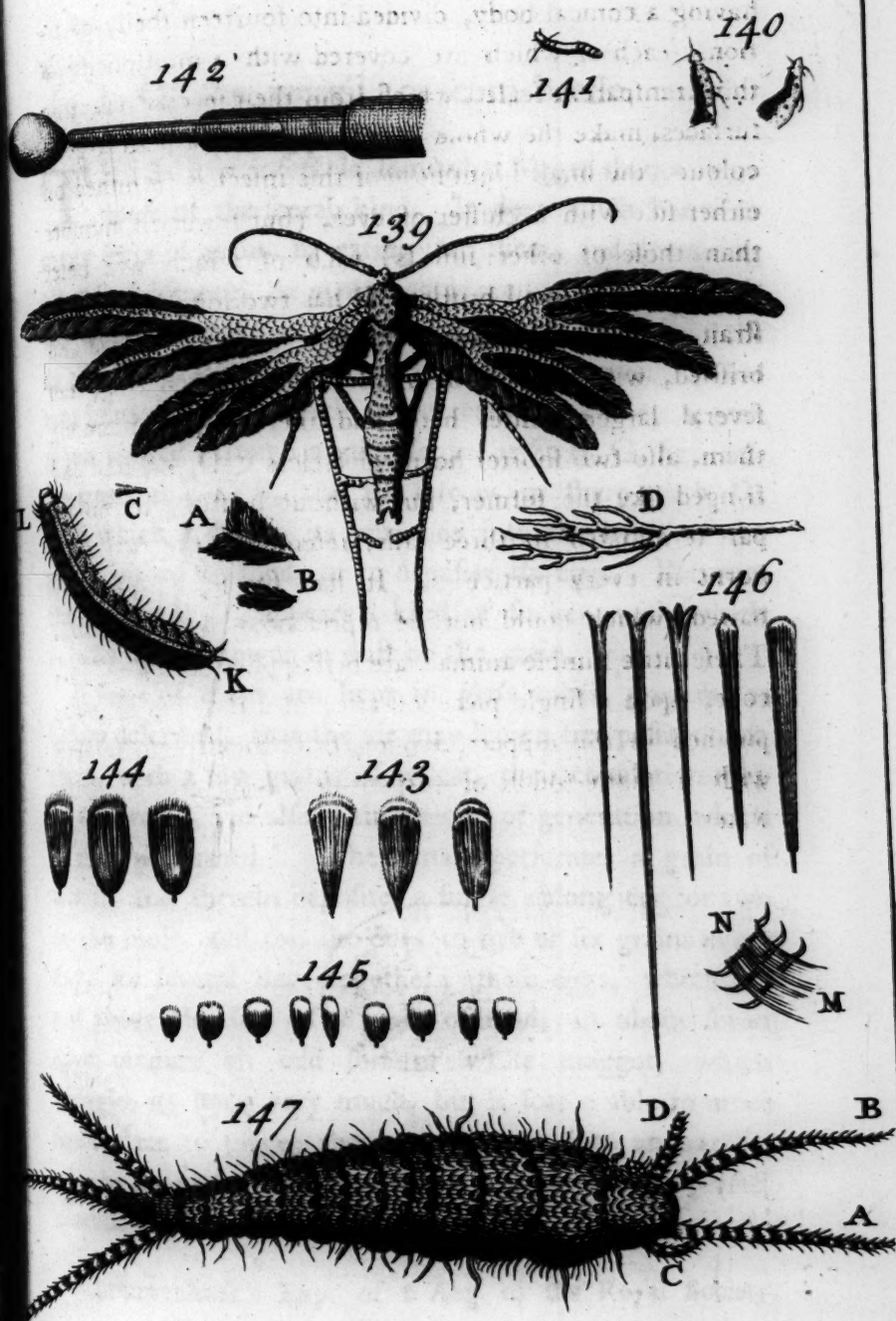
The nymph of the cloaths moth, called by Mr. Hook, the silver coloured book-worm, is a curious object. It is a small silver coloured shining worm, and is often found scudding among books and papers. Fig. 147. represents this worm as it appears in the microscope,

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having

* Leeuwenhoek's Exp. & Contemp. Epist. 71. p. 246.

having a conical body, divided into fourteen shelly partitions, each of which are covered with a multiplicity of thin transparent scales, which from their several reflecting surfaces, make the whole animal appear of a perfect pearl colour: the small blunt head of this insect is furnished on either side with a cluster of eyes, (but fewer in number than those of other insects) each of which was beset with a row of small bristles. It has two long horns A B, strait and tapering towards the top, curiously ringed and bristled, with a girdle of smaller hairs at each ring, and several larger bristles here and there dispersed among them, also two shorter horns or feelers C D, knotted and fringed like the former, but without bristles; its hinder part terminated in three tails, resembling the two long horns in every particular. It had six legs scaled and haired, which could not be represented in this position. These little nimble animals are best applied to the microscope, upon a single piece of talc, or a thin slip of glass, pinched in the nippers, having first stuck them thereto with a slight touch of turpentine, or a drop of gum water.



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1. The first part of the document is a list of names and addresses, which appears to be a directory or a list of contacts. The names are written in a cursive script, and the addresses are listed below them. The list includes names such as "John A. Smith", "Mary E. Jones", and "Robert L. Brown".

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1940-1941

1952

Of the weevil, or corn-beetle.

THIS little insect is somewhat bigger than a large louse of the scarab kind. It does much harm to many sorts of grain, by eating into them, and devouring all their substance. As many people are unacquainted with the weevil, I have exhibited a picture of it, in fig. 148. of the full size it appears of to the naked eye. It has two jointed horns, which are represented as they appear when viewed through a microscope, at E, H, G, fig. 149. Its trunk at E D B, and its forceps or sharp teeth D, with which it gnaws its entrance into the heart of the grain, either for food, or to deposite its eggs. Between the forceps at D, appears a kind of sucker, with which it licks up the flower or dust of the grain.

If some of them are kept in glass tubes, prepared as before described, that the air may have a free passage into them, with a few grains of wheat, their copulation may be discovered, and also their manner of generation, which is thus performed ^f. The female perforates a grain of wheat, and therein deposite a single oblong egg or two at the most, and this she does to five or six grains every day, for several days together; these eggs, which are not above the size of a grain of sand, in about seven days produce an odd sort of white maggot, which wriggles its body very much, but is scarce able to move from place to place; the maggot turns into an aurelia, which in about fourteen days comes out a perfect weevil.

^f Leeuwenhoek's Exp. of 6 Ang. to the Royal Society.

Of the flea.

THES E little creatures are a surprizing object, when examined by the microscope; they are male and female, and undergo the same changes as the silk-worms do. They deposite their eggs at the roots of the hair ^z of dogs, cats, and other animals, and by a glutinous matter stick them fast thereto; one of these eggs is represented magnified in fig. 150, and at 151. the same egg broken by the worm, fig. 152, hatched therein. This worm ^h contains the flea, and is composed of several annular divisions, thinly set with long hairs, having at its head two extremely minute horns at A; these worms feed upon the juices of the body whereunto they closely adhere. They are very nimble, but if disturbed, roll themselves suddenly into a round figure, and continue motionless for some time; after which they open themselves by degrees, and crawl swiftly away. They endeavour to conceal themselves when their change draws nigh, eat nothing, lie quiet, and appear dying, but if placed before the microscope, will be found with the web in their mouths, weaving a covering round them; the inside of which is perfectly white, but its outside as it were soiled with dirt. In this bag they put on the chrysalis, which is represented at fig. 153. divested of its vermicular skin. About two or three days before they break forth from this confinement, their colour darkens, and as soon as they issue from the bag, are perfect fleas, and able to leap away. A microscopic picture of a perfect flea is represented by fig. 158.

It

^z Phil. Transf. No. 249.
Epist. 76.

^h Arc. Nat. Tom. iv.

It is all over adorned with a curiously polished coat of armour, or hard shelly scales, neatly jointed and folded over each other, and beset with long spikes, almost like porcupine's quills: its neck bears some resemblance to a lobster's ⁱ tail: its head is adorned on either side with a beautiful quick and round black eye; behind each of which appears a small cavity, in which moves a thin film, set with small transparent hairs, which may probably be its ear ^k. From the fore part of its head, proceeds a pair of little jointed hairy horns, or feelers A B. Between these and its two fore legs C D, is situated its piercer or sucker, that included a pair of darts, which after the piercer has made its entrance, are probably thrust farther into the flesh, to make the blood flow from the adjacent parts, that it may be sucked up; and seem to occasion that round red spot, with a hole in the center of it, which we commonly call a flea-bite. This piercer, its sheath opening side ways, and the two lancets within it, are very difficult to be seen ^l, unless the two fore legs, between which they are usually folded in, and concealed from view, are cut off close to the head; for a flea rarely puts out its piercer, except at the time of feeding, but on the contrary keeps it closely folded inwards; one way therefore of coming at it, is by cutting off the head first, and then the fore legs; since in the agonies of death, it may easily be managed and brought before the microscope. But this requires a great deal of patience and dexterity. Therefore another more likely way to succeed in this experiment, is, when the flea is just dead, to take hold of its back with a pair of nippers, and then apply it to the sixth magnifier; and having a small sewing needle ready fixed in a handle, I have been able to press

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the

ⁱ Power's Micro. Obs. p. 2. ^k Hook's Micro. p. 210.
^l Arc. Nat. Tom. iv. p. 332. Phil. Trans. No. 249.

the horns forward with the point of the needle, and its two fore legs nearer to the body; and this whilst I was looking through the microscope; by which means I could then exactly see where to place the point of the needle, so as to raise up the piercer in the situation D E, as expressed in fig. 154. which represents a part of the flea's head; and at the same time I have opened the piercer, and separated its two lancets, and this without cutting off any part of the flea, fig. 154. A B C are the two horns, and D E are the two sides of the piercer, which are partly hollow, that they may the better include the lancet, or dart, which in this figure appears to be but one, but if carefully separated, will be found to consist of two parts, as in the next figure 155; whereof G H and G I represent as before the two parts of the piercer beset with several hairs, and G H shews the two darts, but not separated. At fig. 156. they may be seen asunder, whereof L O, L N, are the two hairy parts of the piercer before spoken of, and L M, O L P the darts; in L M may be seen the cavity, which includes or receives the other dart L P; when they are shut up between the flea's fore legs, all the four make but one proboscis.

Besides these two legs before spoken of, which adhere to the head of this little creature, it has four others, which are joined to its breast; these six legs the flea clutches up altogether; and when he leaps, springs them all out at the same instant, and thereby exerts his whole strength at once, which carries him to a surprizing distance, above hundred times its own length. Its legs have several hairy joints, which terminate in long hooked claws; as in fig. 158.

If the eggs of fleas be constantly warm in one's bosom (it has been observed that) in the midst of summer, they hatch in four days; then feed the maggots with dead flies,

flies, which they greedily suck. In eleven days they come to the full perfection of the reptile state, when the maggot spins its bag, and in four days more changes into a chrysalis; after lying in which condition nine days, it becomes a perfect flea. It is then immediately capable of coition, and in three or four days lays eggs; so that in ^a twenty-eight days, a flea may come from its egg, and propagate its kind; and their vast increase will not seem so great a wonder if we consider, that from March to December there may be seven or eight generations of them; after having laid their eggs they soon die, as all creatures do that undergo such like changes.

If you keep fleas in such a glass tube, as is before described, so as to admit fresh air, their several actions may be observed, and particularly their way of coupling, which is performed tail to tail. The female (which is much the larger) standing over the male; they will also be seen to lay their eggs, not all at once, but ten or twelve in a day for several days successively; which eggs hatch in the same order.

A dissection of the flea may be effected in water, the ^a stomach and bowels, with their peristaltic motion, may plainly be distinguished, and also the testes and penis, together with veins and arteries, minute beyond conception. Mr. Leeuwenhoek affirms, that he has likewise discovered innumerable animalcules, shaped like serpents, in the semen masculinum of a flea.

^a Arc. Nat. Tom. iv. p. 325. ^a Ibid. p. 335.

Of the louse.

THE transparency of its skin enables us by the help of the microscope, to discover the motion of the muscles °, (which unite in an oblong dark spot in the middle of its breast) as the louse moves its legs; and also in the head, when the horns are moved, and in the several articulations of its legs. The peristaltic motion of the intestines is really surprizing, which is continued from the stomach through the guts to the anus. The various ramifications of the veins and arteries, which are white, and a regular pulse may be also discerned. From its head proceeds two hairy horns BB, fig. 159. with four joints. Its two black eyes are shewn at CC, fenced round with several small hairs; it has six legs, covered with a very transparent shell, and jointed exactly like a crab's or lobster's claws; each leg hath five joints with several small hairs interspersed about them; at the end of each is two sharp hooked claws, as may be seen in the figure, unequal in length and size; one of which resembles that of an eagle, but the other of the same foot ^p stands strait out, and is very small; between these two is a raised part or knob, most exquisitely contrived for performing those motions of walking and climbing up the hairs of the head; for when it walks, by having the lesser claw G set so much short of the bigger H, that the former does not touch, and by means of the small joints in the latter, it is able to bend it round, and so with both claws to grasp and hold fast the hairs ^q. From its snout at the hole D, when the louse is going to feed, it pushes out a pointed

° Phil. Transf. No. 284.
Micro. p. 212.

^p Ibid. No. 94.

^q Hook's

pointed part, which is represented at fig. 157. whereof L O P is the snout part of the louse's head. At O is the nipple, from whence the sheath, or case M, and from within this also, the piercer^{*} or sucker N is pushed out; at N, its point is somewhat cleft. These are thrust into the skin to draw out the blood and humours it feeds on; for Mr. Hook placed a louse upon the back of his hand that had been fasting two or three days, which immediately thrust its sucker into the skin, and he could plainly see a small current of blood come directly from its snout in a fine stream to the fore part of the head, and then, to fall into a roundish cavity; it passes again in a like stream to another circular receptacle in the middle of the head at A, from thence through a smaller vessel to the breast; and then to a gut that reaches to the hinder part of the body, where in a curve it turns a little upwards. In the breast and gut the blood without intermission is moved with great force, and in the gut with such a strong propulsion downwards, and such a contraction of the gut as is surprizing. In the upper part of the crooked ascending gut the propelled blood stands still, and seems to undergo a separation^{*}; part of it becoming clear and waterish, while certain little black particles pass downwards to the anus. The thorax is cased with a transparent horny substance, through which the blood was variously distributed; and at I, appeared a pretty big white substance; many very small milk-white^{*} vessels were discernable between its legs, out of which on either side were many minute branchings. The belly is covered with a thin transparent skin; at the upper end of this its stomach K K is placed, and the white spot L;

at

^{*} Leouwenhoek's Exp. & Con. p. 354. ^{*} Phil. Trans.
No. 102. ^{*} Hook's Micro. p. 213.

at the extremity of the tail are two semicircular parts covered all over with hair.

Place a louse on its back and two darkish bloody spots will appear: the larger in the middle of the body, and the lesser towards the tail. In the larger spot a white film ^{*} or bladder contracts, and dilates upwards and downwards from the head towards the tail; the pulse of which is followed by a pulse of the dark bloody spot, in or over which the white bladder seems to lie. This motion of systole and diastole is seen best when the louse is grown weak; the white pulsing bladder seems to be the heart, for on pricking it the louse instantly dies. The lower darkish spot is thought to be the excrement in the guts.

The males have stings ^{*} in their tails, the females none: the females lay eggs or nits, from whence lice are produced perfect in all their members, and undergo no farther change.

Mr. Leeuwenhoek observed that in six days one of them had laid fifty eggs, and dissecting it, he saw as many more in the ovary; concluding from thence that it would have laid an hundred eggs in twelve days. These eggs hatched in six days, would probably produce fifty males and as many females; and these females coming to their full growth in eighteen days, might in twelve days more probably lay an hundred eggs also, which eggs in six days farther, the time required to hatch them, might produce a young brood of five thousand; so that in eight weeks a louse may see five thousand [†] of its own descendants.

Upon

^{*} Power's Micro. Obs. p. 9. ^{*} Arc. Nat. Tom. ii. p. 77.

[†] Ibid. p. 77. ^{*} Arc. Nat. Tom. i. p. 78.

Upon an oblong slip of glass, a louse may be easily dissected in a small drop of water and applied to the microscope; thus five or six eggs ready to be laid may be found in the ovary of a female, with many others of a less size. In the male the penis is remarkable, and also the testes, whereof it has a double pair. The females appear very white if fasting, and even when fed are less red than the males.

The vermin adhering to and feeding on the bodies of different animals, are commonly called lice.

Insects are infected with vermin that feed^a on and torment them; several beetles have lice on them.

The earwig is troubled with minute insects, which stick like lice on the several parts of the body, especially under the setting on of its head. They are white like mites, but smaller; are round backed, flat bellied, long legged, especially the two foremost; the same has not been observed on any other animal.

Snails of all kinds have insects feeding on them. Small red lice are frequently to be seen about the legs of spiders.

White lice are commonly found on humble-bees, on ants, on fishes, &c. and probably very few creatures are free from them.

The polipe also is not exempt from vermin of this sort.

There is another sort of louse found about unclean people, called a crab-louse.

Seignior Redi at the end of his treatise *De Generatione Insecto*, hath obliged us with microscopic drawings of several sorts of lice, that feed upon the bodies of different animals, to which I refer the reader.

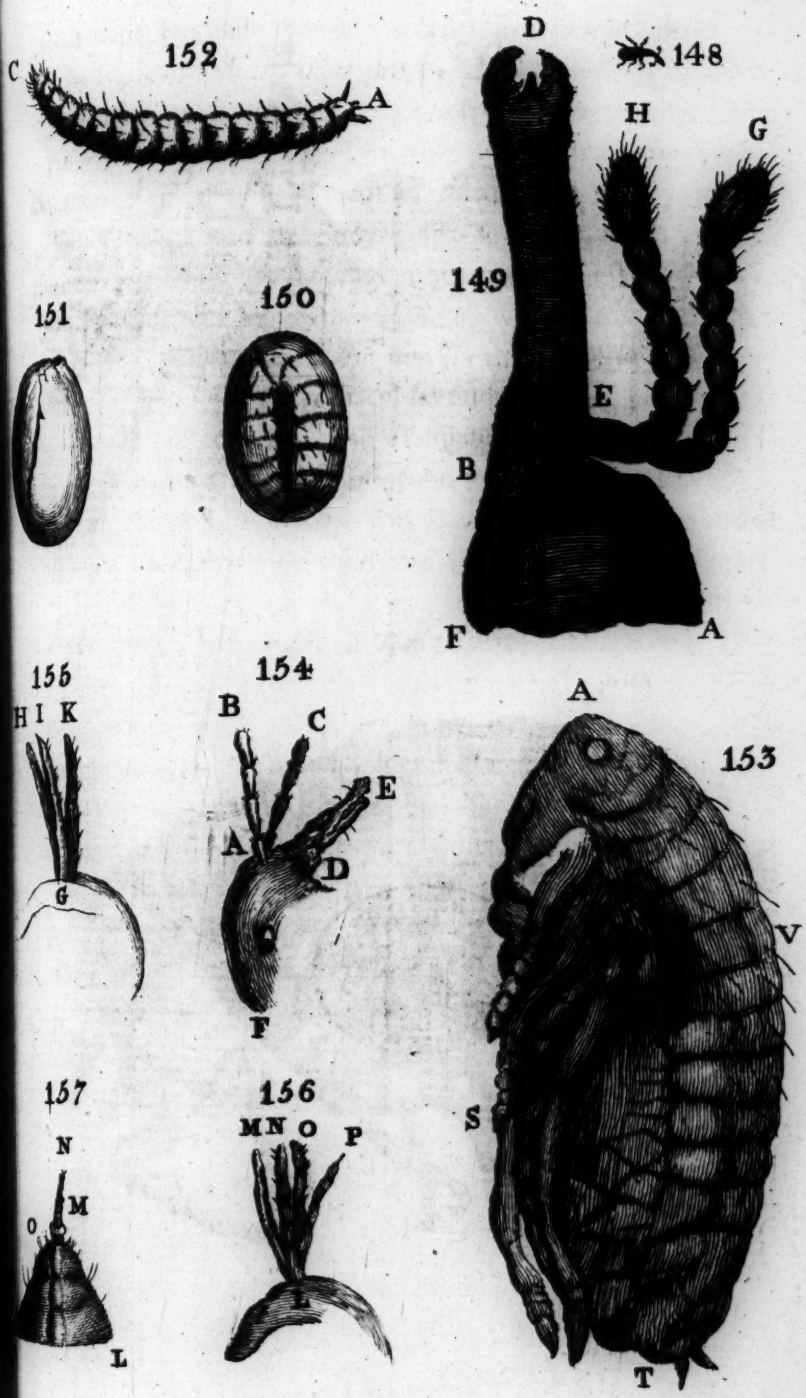
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^a Phil. Transf. No. 283.

In the hawk and turkey hen he observed three sorts, four in the wild duck, in the wild goose, swan, kestrel, and plover two; yet there are several sorts of birds which have either the same sort of lice, or some nearly like them. The kestrel hath a sort of lice differing only in colour from those of the raven; and the raven others, like those found upon the egret: on the wood-pecker and chafinch are some resembling those of the starling; on the large wild duck are some much like those of the wild goose. It is also observable, that the bigness of each bird's lice bears no adequate proportion to the bigness of the birds they are found upon; but that on the largest birds both large and small lice of different kinds may be found; for on the black-bird hath been seen some as large as those on the swan.

There is also a little animal in shape and colour like a louse, commonly found among the leaves and covers of books, and in rotten wood; it has a swift motion and runs by starts; it is called a wood-louse ^b or wood-mite. If this animal be stuck upon the point of a very fine sewing needle with a little turpentine, it will be found a very curious object; its whole body being cased in annular circles, full of silver hairs, especially towards the tail, with six legs, that terminate in two talons; it hath two horns, but pointing backwards; its eyes are of a golden colour, and pushed out or drawn in at pleasure; it hath also two pointers before like a pair of pincers.

^b Power's Micro. Obs. p. 10.



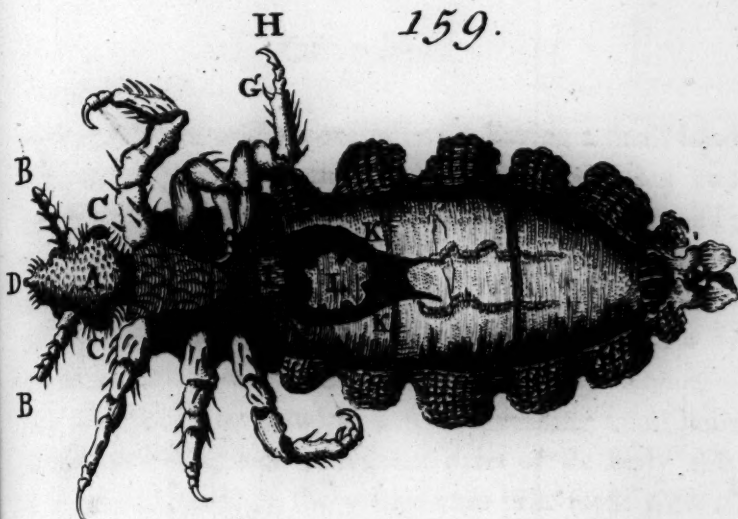


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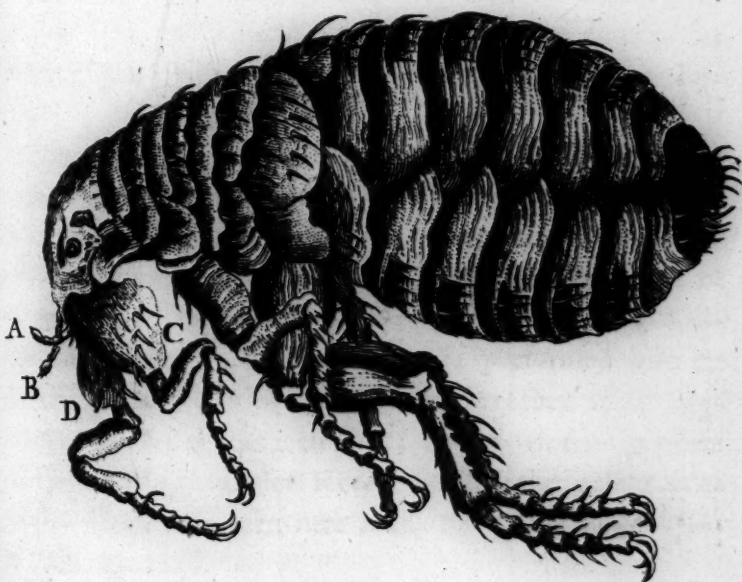
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159.



158.





Of mites.

THEY are crustaceous animals, having a small head in proportion to their bodies, a sharp snout and mouth like that of a mole ^c; when open it appears red; they have two little eyes, some have six legs, others eight, each of which terminate in two hooked claws: the divisions of the head, neck, and body are easily discernable by the microscope; the hinder part of its body is plump, and of an oval form; with a few exceeding small hairs issuing therefrom, and from other parts of its body also. The female lays eggs, the young ones issue forth with all their members perfect, though extremely minute; they cast their skins several times before they attain their full growth.

Fig. 106. represents one of the mites in cheese; its head is seen at A, and exactly answers the description before given. One of a mite's eggs is seen at fig. 105.

They may be kept alive many months between two concave glasses, and applied at pleasure to the microscope; by often looking at them they may frequently be seen in coitu ^d, conjoined tail to tail, for though the penis of the male be in the middle of the belly, it turns backwards like the rhinoceros. The coitus is performed with an incredible swift motion. In warm weather their eggs hatch in twelve or fourteen days; but in winter-time and cold weather not under several weeks: the young ones may be frequently seen near a day struggling to get clear of their egg-shell.

^c Power's Mic. Obs. p. 16.

^d Arc. Nat. Tom. iv. p. 360.

Of the wandering mite.

TH E S E creatures appear to the naked eye to be a kind of black mite, though much nimbler and stronger than the cheese mites, but on viewing them in the microscope, they will be found to be a very fine crustaceous insect, like fig. 161. with a protuberant oval shell indented with several small pits, covered all over with white bristles; they have eight legs, each of them furnished with a sharp claw at the end. The thorax was covered by two shells, its snout taper with a knobbed ridge ^e running along the middle of it; just over each of its eyes arose two very long and strong bristles, its eyes black and smooth like those of bigger insects. These mites are to be met with on almost any substance where they can get food.

Another sort of mite as delineated by Dr. Hook, is represented in fig. 162, covered with a curiously polished shell, which reflected the light from all sides.

These creatures are very much diversified in shape and colour, and in several other circumstances, according to the nature of the substance out of which they seem to be fed ^f, being in one longer, in another rounder, in some more hairy, in others smoother, in this nimble, in that slow, here pale and whiter, there browner, blacker, or more transparent. They are to be met with almost on all kinds of substances that are mouldy or putrifying, in oatmeal, and in malt-dust; there are mites bred among figs ^g, in hay, and in the powder that falls off dried roots ^h. They are voracious animals, and devour

not

^e Hook's Micro. p. 206.^f Ibid. p. 214.^g Phil.

Transf. No. 333.

^h Power's Micro. Obs. p. 18.

not only cheese, but also all sorts of dried flesh, fish, fruits, and grain, and almost every thing besides that has a certain degree of moisture, without being over-wet. Fig. 164. represents a small hair of a mite as delineated by Mr. Leeuwenhoek, which a certain gentleman compared to an Indian or Japan caneⁱ, with several joints, and said it appeared to him through the microscope as if sharp twigs were sprouting out of each joint. And fig. 163. represents another hair or bristle of a mite magnified, which was spicated, or bearded like the ear on the seed-beard of some grass. Every bristle on its body and legs had the same formation; yet all mites are not so; for of seven or eight which were inclosed together, but one of them was found whose bristles were all of this make, in the rest the horns only were spicated.

Their mouths open horizontally to the right and left, like that of a wasp; several of them being shut up together without food for some days, some were found dead, and the survivors preying on them; by which means their manner of feeding^k was observed, which is very remarkable; for they thrust one mandible forwards, and draw the other backwards at the same time, and thus they do alternately; so that they seem to grind their food. After feeding they munch or chew the cud.

Mr. Leeuwenhoek hath observed that mites in cheese turn into aurelias, and from thence to flies; when they turn into aurelias^l they are inclosed in a thin transparent membrane, which in some measure screens them from the insults of the maggots that swarm in cheeses. He also observed some of the flies produced from these cheese-worms, that he kept in a glass tube in which he had put

H cheese

ⁱ Power's Micro. No. 333.
No. 262.

^k Ibid. No. 284.

^l Ibid.

cheese for them to feed upon, had coupled; and so after laid eggs of an oblong figure, and then died: from these eggs came young worms, which also fed on the cheese, and when he judged them to be at their full growth, and the weather began to be cold, he took six of the biggest, and carried them about him; and a few days after he observed that four of them were changed into aurelias, that two worms were dead, and two flies skipping about the glass; he repeated the same thing in January, and with the like success; when he kept them in the cold, little or no sign of life or motion appeared; but as soon as he put them into his pocket, they were as brisk as in summer. Upon opening an aurelia that had never produced a fly, a dead one was found within it, which had been making its efforts to get out, but was not strong enough to effect it.

These vermin creep into the cabinets of the curious, and destroy their choice collections of insects: but to prevent this, keep in your drawers, &c. a continual supply of camphire, whose hot and dry effluvia will penetrate, shrivel up, and destroy the tender bodies of these little mischievous plunderers.

Of a crab-like insect.

THIS insect is about the bigness of a large mite, and of a very curious form, as delineated in fig. 167; it had ten legs, eight of which a a a a terminated in very sharp but double hooked claws, being those it walked upon, which were shaped much like those of a crab: the two other claws A A, that were the foremost of all the ten, seemed to branch out from its head, and were exactly formed like crabs, or lobsters claws, as are expressed in the figure, whose ends terminated in a pair of pincers, (with which I have often seen him stroke those other claws E E) which grew out of his snout; in walking the creature elevated the former above its head and body; its eyes were situated about d d, its head was covered with a kind of scaly ⁿ shell at F, its thorax G G with two smooth scales, and its back with eight knobbed ones H H. These insects are frequently to be met with amongst books and papers that come from China, when first unpacked.

ⁿ Hook's Micro. p. 208.

Of the semen masculinum.

SPONTANEOUS generation is a doctrine so generally exploded, that a disproof of it is altogether needless in this place, it being put beyond all dispute that all animals and vegetables owe their production to parent animals and vegetables; and that animals are from animalcula °. These animalcula being originally in the semen of the male, and not in the female; therefore can never come forward or be formed into animals of their respective kinds, without the ova in the female †.

By the assistance of a good microscope, myriads of animalcules may be discovered in the semen masculinum of animals, alive and vigorous; though so exceedingly minute, that it has been computed 3,000,000,000 of them are not equal to a grain ‡ of sand.

The general appearance of the animalcules in the semen masculinum of different creatures is very much the same, that is, their bodies all seem to be of an oval form, with long tapering slender tails issuing therefrom, somewhat resembling tadpoles: though their tails in proportion to their bodies are much longer than those of tadpoles. And the animalcules in the semen of fishes have tails still longer and slenderer than either, insomuch that the extremity of them is rarely to be discerned. Their general appearance as above described is shewn fig. 187.

Mr. Leeuwenhoek, upon viewing the milt of a cod fish § with a microscope, observed therein such prodigious numbers of living animalcula, with long tails incessantly moving

• Phil. Transf. No. 192. † Vide Harris's Lex. Tech. under the word Generation. ‡ Vide Keil's Anat. p. 116.
 § Phy. Collections, No. 1. p. 3.

moving to and fro, (he observed the same thing in the milts of pikes or jacks) that according to his computation 10,000 of them might be contained in the quantity of one grain of sand *. Whence he argues, that there are more living animalcula in the milt of one cod-fish, than there are people alive upon the face of the whole earth, at one and the same time. He computes one hundred grains of sand to make the diameter of an inch, then a cubic inch will contain a million of such sands. And as he found the milt of the cod-fish to contain fifteen inches, it must contain fifteen millions of quantities as big as a grain of sand; and if each of these quantities contain 10,000 animalcules, the whole must contain one hundred and fifty thousand millions. Then to calculate the number of people, he reckons a great circle to contain 5,400 Dutch square miles: whence he calculates the earth's surface to contain 9,276,218 such square miles: and supposing one third of the whole or 3,092,072 miles to be dry land; and of this two thirds or 2,061,382 miles to be inhabited. And supposes farther, that Holland and West-Frizeland are twenty-two miles long, and seven broad, which makes 154 square miles: the habitable part of the world is then 13,385 times the bigness of those places.

If the people in these two provinces are supposed a million, and that all the other parts of the world are as populous as these, which is improbable, there would be 13,385 millions of people on the face of the whole earth: but the milt of this fish contained 150,000 millions of animalcules, which is ten times more than the number of mankind.

The seminal vessels of a cock † being opened, and a small drop of the semen squeezed out, and applied to the

H 3

microscope,

* Arc. Nat. Tom. i. Part ii. p. 9.

† Phil. Transf. No. 279.

microscope, great numbers of animals were seen swimming therein in legions, and crossing one another like clouds in a stormy day, as brisk as if the cock was newly dead ^u, although it was killed the day before; they appear as at fig. 168. if viewed with due attention, and with the greatest magnifiers, otherwise only in the form of eels.

Mr. Leeuwenhoek, in the spring-time, when the frogs engender, opened the testicles of the male ^z, and on applying some of the seminal matter to the microscope, multitudes of animalcules appeared therein, about one thousandth part of the thickness of a human hair; and there seemed to be ten thousand of them at least to each one of the female ova; their form is as represented in fig. 169.

Mr. Leeuwenhoek's method of computing the size of animalcules was this, he placed an hair ^y of his head near them, which hair appeared an inch in breadth; and being satisfied that sixty of the animalcules could lie within that diameter; whence their bodies being spherical, 216,000 of them are but equal to a globe, whose diameter is no more than the breadth of such an hair. Another method of his also follows.

He first supposed a drop of water equal to a pea; then took a little quantity of water, of a round figure, as big as a millet grain; and reckoned this to be one ninety-one part of a pea ^z; for when the axis of a millet seed makes one, that of a pea will make four and half, whence it follows, that the seed of a millet is at least the one ninety-one part of a pea; this small quantity of water he put into a very slender glass tube, dividing by this means that little water into twenty-five or thirty parts, and found

^u Arc. Nat. Tom. ii. Part. ii. p. 369. ^x Arc. Nat. Tom. i. Part. i. p. 51. ^y Phil. Trans. No. 270. ^z Ibid. No. 131.

more than an hundred animalcula in the one thirtieth part of water, equalling the bigness of a millet seed. Whence it appears, that if one thousand are to be seen in the one thirtieth part of a millet seed, there may be seen thirty thousand in one such whole seed; and consequently in a drop of water ninety-one times bigger, there may be seen 2,730,000. Besides he compared the water to the bulk of a grain of sand; that if the axis of a grain of sand be one, that of a drop of water is at least ten, consequently a drop one thousand times bigger than that grain of sand, and therefore there are 1,000,000 of animalcula in one drop of water, at the rate of one thousand little animals in that quantity of water.

^a In the same manner he also computed that 4,096,000 eggs were in the roe of a crab. Each of which received its nourishment by a string from the crab's body.

To view the animalcules in the milt or soft roes of fishes, squeeze out a little of it, and putting the quantity of a pin's head upon a glass, dilute it with river or rain-water, till they have sufficient room to swim freely about, and shew themselves to advantage.

N. B. the eggs ^b in the roe and animalcules in the milt of fishes of one year old, are as large as in those of the same species of twenty years old.

Some of the feminal matter taken from the testicles of a dog ^c, abounded with animalcules in form of fig. 170. and some of them remained alive after having been kept seven ^d days in a glass tube.

The testicles of a hare, although four days ^e dead, were found to be exceeding full of animalcules, like those

H 4

^a Arc. Nat. Tom. i. Part ii. p. 339. ^b Ibid. Tom. iii. p. 188. ^c Ibid. Tom. i. Part ii. p. 160. ^d Ibid. p. 150, and 49. ^e Ibid. Tom. i. Part ii. p. 160.

those in dogs, swimming in a clear liquor, but without motion.

A female rabbit being killed immediately after the coitus, and the uterus opened, innumerable quantities of animalcules were found in a small drop taken from the mouth of the fallopian tube, where it opens into the matrix; but none were discerned in the uterus itself, or farther along the tube; they had long tails, and mostly six transparent globules appeared on the body of each, as in fig. 171. A; though some had only one globule at the end of the body, and another in the tail, as fig. 171. B.

A buck being killed in rutting-time, the vasa deferentia were found turgid, and full of a milky fluid, a drop of which diluted with a drop of warm water, just enough to change its colour, and then applied before the microscope, appeared full of animalcules moving very briskly ^g.

A drop of the feminal matter taken from the testicles of a ram, flowed with animalcules in as great numbers as that of other creatures; but with this difference, that they swam in droves together the same way, and seemed to follow their leader ^h as sheep do. Mr. Leeuwenhoek found so much pleasure in this observation, that he called in some neighbours to share it with him.

This ingenious enquirer after nature, opened the uterus of an ewe, about seventeen days after she had been coupled with a ram; and in one of the cornea observed a little reddish fleshy substance, wherein no shape could be distinguished, which he extended very gently out of the round in which it lay, and could plainly perceive

^f Arc. Nat. Tom. i. Part ii. p. 168. ^g Phil. Trans. No. 284. ^h Leeuwenhoek's Epist. Phy. p. 388.

ceive the formation of all the vertebræ, with the blood-vessels and ramifications passing over them, and could see the spinal marrow in two places ¹, and distinguished not only the head, but also the mouth, brain, and eyes, the bigness of two grains of sand, and clear as crystal; he likewise saw the ribs and intestines, though the whole creature was no longer than the eighth part of a pea. After which he opened the uterus of another ewe ^k, three days from the coitus, and searching the liquor coming therefrom with a magnifying glass, observed a little particle the size of a grain of sand; and examined it with a very good microscope, and with great pleasure found it to be an exceeding minute lamb, lying round in its integuments, and could plainly discern its mouth and eyes.

The human semen has also been viewed by the microscope, and found to be as plentifully stocked with animalcules, as that of other animals: Mr. Leeuwenhoek has seen more than ten thousand living creatures moving in a quantity of the fluid part thereof, no bigger than a grain of sand: and in the thicker parts, they were so thronged together, that they could not move for one another; their size was smaller than the red globules of the blood, and even less than a millionth part of a grain of ^l sand, their bodies roundish and flat before, as in fig. 172. but ending sharp behind. Their tails are exceedingly transparent, and five times longer, and slenderer than their bodies. They move by the agitations of their tails in various windings, after the manner that eels swim.

The ^m animalcules in the semen masculinum of all creatures differ but little in shape or bigness, for which
reason

¹ Arc. Nat. Tom. i. Part ii. p. 164. ^k Ibid. p. 173.
^l Arc. Nat. Tom. ii. Part ii. p. 61, 96, 286. ^m Ibid.
Tom. iv. p. 30.

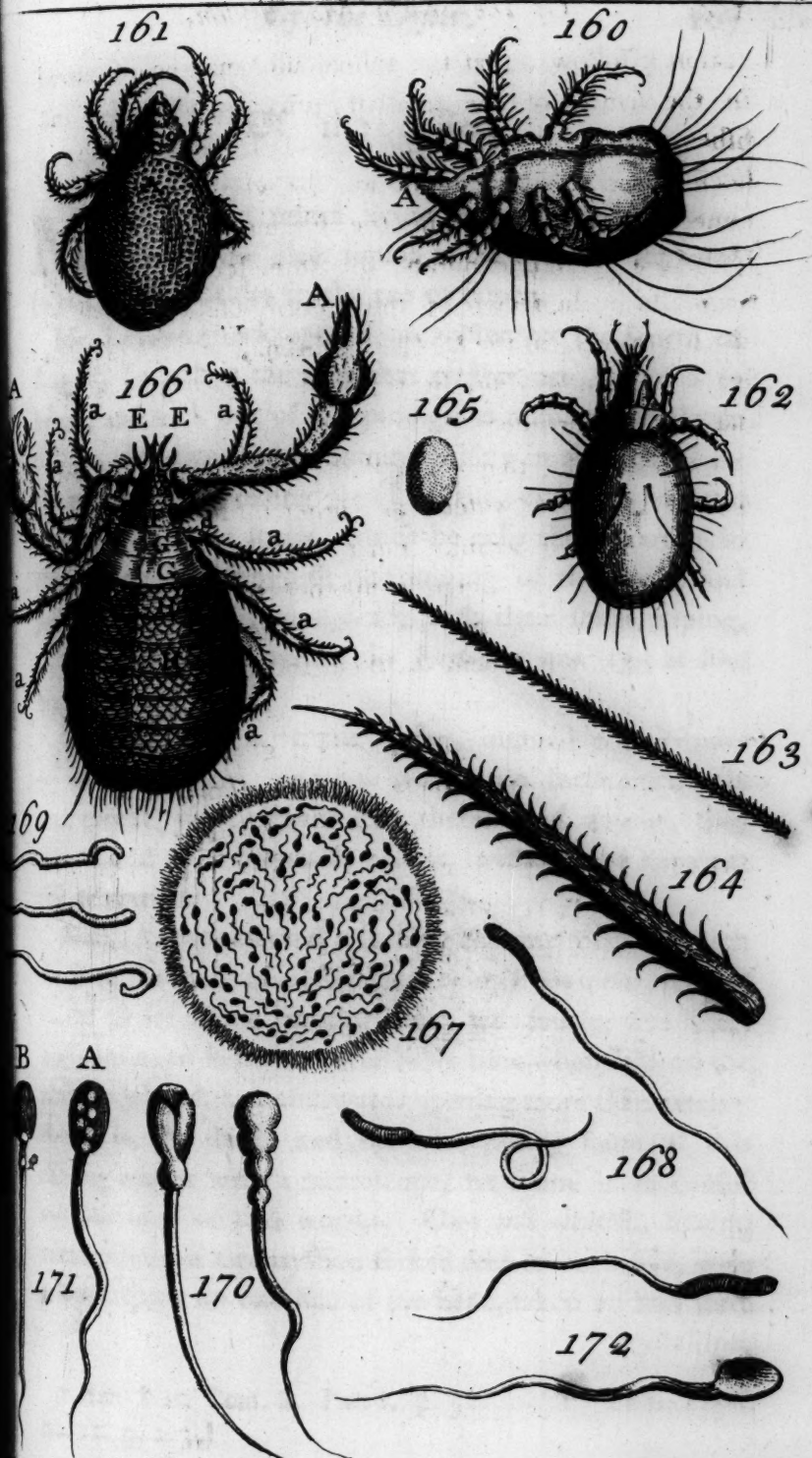
reason it follows, that the animalcules may be discovered in the semen of the smallest birds, quadrupeds, and fishes; nay, and even in insects to. For Mr. Leeuwenhoek affirms, that he found in the white matter he had sometimes squeezed from the hinder parts of male spiders, a prodigious number of animalcules. He found them also in the semen of the dormouse, in oysters, in silkworms, in the labella minima, or small dragon fly, the common fly, in the male flea, in gnats, and many other insects*.

It is observable that amongst the many species of animalcules found in waters, and other infusions, there are none like those in semine; but that these last, in all sorts of creatures, have a general likeness to each other, and appear in continual motion without any intermission, if the fluid be but sufficient for them to swim in.

It is farther observable, that no animalcules can be found in the blood, spittle, urine, gall, chyle, or any other of the humours, except the semen only.

* Phil. Transf. No. 279. ° Arc. Nat. Tom. i. Part ii. p. 27. ° Ibid. Tom. ii. Part i. p. 144. ° Ibid. Part ii. p. 442. ° Ibid. Tom. iv. p. 19. ° Ibid. ° Ibid. p. 20. ° Ibid. p. 22. ° Ibid. p. 294.

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Arc. Nat. Tom. i. Part ii. p. 144.
Ibid. Tom. ii. Part i. p. 144.
Ibid. Tom. ii. Part ii. p. 442.
Ibid. Tom. iv. p. 19.
Ibid. p. 20.
Ibid. p. 22.
Ibid. p. 294.



10

20-1-7



Of the oyster.

MANY little round living animalcules have been found in the clear liquor of an oyster ^y, supposed to be the animalcules in the roe or semen.

Mr. Leeuwenhoek opened an oyster on the fourth of August, (which is the time that oysters are supposed to breed) and took out of it a prodigious number of minute oysters, all alive and swimming briskly in the liquor, by the means of exceeding small organs, extending a little way beyond their shells, which he calls their beards; in these he could distinguish the joining of the shells, and perceived some that were dead, with their shells gaping, and as like large oysters in form as one egg is like another.

Upon opening a female oyster, incredible multitudes of minute oysters, covered with little shells, perfectly transparent, were plainly seen therein; in another they were found of a brownish colour, without any apparent life or motion.

Monf. Azout observed a shining clammy matter, which stuck to the shells of oysters, and being drawn out, shone ^z in the air its whole length, which was four or five lines, and continued so for a considerable time when laid on the observer's hand, and afterwards opening more than twenty dozen in the dark, and then examining some of this shining matter with a microscope, he found it to consist of three sorts of real worms. One was whitish, having twenty-four or twenty-five forked feet on each side, with a black speck on one side of the head, taken by him for a crystalline,

^y Arc. Nat. Tom. ii. Part i. p. 52.
No. 12. p. 203.

^z Phil. Transf.

crystalline, its back like an eel stripped of its skin; the second was red, resembling the common glow-worm, with folds on its back, legs like the former, and a nose like that of a dog's, and one eye; the third sort was speckled, with a head like a foal, and many tufts of whitish hair on its sides. There was a bigger species, that was greyish with a big head, and two horns like those of a snail; it had seven or eight whitish feet, but these shined not.

The two former consist of a matter easily dissolvable, the least touch turning them into a viscous and aqueous matter, which falling from the shell, stuck to the observer's fingers, and shone there for twenty seconds. If any part of it fell to the ground it appeared like a small piece of flaming brimstone, and when shook off nimbly, it seemed a small shining line, which was dissipated before it reached the ground. Some of it was whitish, some reddish, but both afforded a violet colour to the eye. The worms give no light when irritated; and if they do, it lasts but a little while: whereas in those that are not provoked, it continues a good while.

As tainted flesh, rotten wood, bodies of lobsters, and some other kinds of fishes, and other substances, are sometimes found to shine with a light resembling the foregoing, may it not probably proceed from the same cause, viz. from animalcules? Some have also supposed, that the *Ignis Fatuus*, will in a wisp, or jack in a lantern, is nothing else but a swarm of minute insects, that emit light round them in the manner glow-worms do.

Of the muscle.

IN a dissection of the ovarium of a muscle, Mr. Leeuwenhoek discovered numbers of embrio-muscles^a, which appeared as plainly in the microscope as the muscle does to the naked eye; lying with their sharp ends fastened to the strings or vessels whereby they received their nourishment. These minute embrio muscles are in due time laid or placed by the parent, in a very regular and close order, on the outside of the shell; where, by means of a glewy matter, they adhere very fast, and continually increase in size and strength; till becoming perfect muscles, they fall off and shift for themselves, leaving the holes where they were placed behind them, as abundance of muscle shells when viewed by the microscope can shew two or three thousand of these eggs adhering sometimes to the shell of one muscle; it is not certain they are all fixed there by the muscle itself, but are frequently placed there by another muscle. The fringed edge of the muscle, called by Mr. Leeuwenhoek the beard, has in every the minuteest part of it such a variety of motions, as is unconceivable; for being composed of longish fibres, each fibre has on both sides a vast many moving particles, which one would almost imagine to be animalcules^b.

The strings or threads, which we term the beard, are composed of a glew, which the muscle applies by the help of its trunk to some fixed body, and draws out as a spider does its web, thereby fastening itself, that it may
not

^a Phil. Transf. No. 336. ^b Phil. Transf. No. 336. Arc.
Nat. Tom. ii. p. 19. & Tom. iv. p. 423.

not be washed away. If muscles be put into salt and water, they will fasten themselves to the sides of the vessel we place them in.

Scallops, cockles, limpets, perriwinkles, and abundance of other shell-fish, are objects that have as yet been very slightly examined by the microscope; and therefore the serious enquirer into nature's secret operations may here be certain of discovering beauties, which at present he can have no conception of.

Of the itch.

DOCTOR Bononio hath discovered that this distemper owes its rise to little insects ^c under the cuticula, whose continual bitings cause an ousing of the serum from the cutis, and produce those pustules whereby the disease is known.

For on observing people in this distemper pull out of the scabs, little bladders of water with the point of a pin, and crack ^d them like lice upon their nails, from a place scabbed over, and where there was a grievous itching, he picked out a little pustule, and from thence squeezed a thin matter, in which he could but just discern a small white globule; but on applying it to his microscope, found it to be a minute animal of a whitish colour, in shape resembling a tortoise, but somewhat dark on its back; it is represented in fig. 173, at A and B; they have some long hairs, six legs, a sharp head, and two horns, and are very nimble. He repeated this on persons of all ages, sexes, and complexions, and at all seasons of the year, and found the same sort of animals in

^c Bonani Micro. p. 91. ^d Phil. Trans. No. 283.

in most of the watery pustules. They begin to enter in the furrows of the cuticula by gnawing and working in their heads till they are quite got under, where they cause a grievous itching, and force the infected person to scratch, which only heightens the malady: from his frequent observations he also saw one of them drop an egg, almost transparent, from the hinder part of its body, and afterwards saw several others of the same sort, one of which is represented at C, fig. 173.

Hence follows the reason why this distemper is so very catching, since by simple contact these animals can readily pass from one person to another, not only from their swift motion, but by their clinging to every thing they touch; and crawling as well upon the surface of the body, as under the outward skin. A few being once lodged, they multiply apace by their eggs; nor is it any wonder if this infection is also propagated by the sheets, towels, handkerchiefs, or gloves, used by itchy people; since these animalcules may easily be harboured in such things, and will live out of the body two or three days.

This discovery also accounts why this distemper is never cured by internal medicines, but requires lixivial washes, baths, or ointments, made up of salts, vitriols, mercury, sulphur, precipitate or sublimate, or such kinds of corrosive and penetrating remedies as can powerfully kill these vermin in their skin. It is necessary to continue the anointing for some days after the cure seems perfected; for though the ointment may have destroyed all the living animalcules, it may not probably have killed their young in the eggs, which are laid in nests in the skin, which if suffered to be hatched may renew the distemper.

Of animalcules in the teeth.

THESSE are to be found in great numbers of different kinds, in the whitish matter that sticks between the teeth of men, women, and children^e; but especially between the grinders, although they wash their teeth frequently; but from people that are more careless, a sort of eels are found. The first sort A, fig. 174. move along very swiftly, in spittle or water without bubbles. The second sort seen at B, fig. 174. move in the direction of the dotted line. The third sort is seen at E, and the fourth sort at F.

They all die if vinegar be put to them; from whence it seems probable, that if the teeth and gums be frequently washed with it, it may be a means to preserve them from these creatures.

Of the snail.

THIS slow paced slimy animal hath many curious observables. The first are its four eyes, like atramentous spots, fixed at the ends of its horns, or rather at the ends of those black filaments, or optic nerves^f that are sheathed in its horns, which it can thrust out, draw in, turn, or direct as it finds occasion. If when the horns are fully extended, you nimbly clip off their extremity, and place them before the microscope, either upon the object carrying glass, or stick the end of them with a little turpentine to the point, they may very easily be examined in the microscope, with all the

^e Leeuwenhoek's Ex. & Con. p. 40. Tom. iv. ^f Power's, Micro. Obs. p. 36. Spect. de la Nat. Dial. xi.

the magnifiers, and will be found to be two hemispherical eyes. And when the stump is re-extended, it will appear evidently hollow, or tubular to the naked eye.

Snails partake of the nature of both sexes, insomuch that as soon as one has impregnated the other, the same act of generation is immediately returned; each of them, eighteen days after these approaches, drop and conceal their eggs in the earth; the young of which, when hatched, appear with shells compleatly formed ^z.

If you would view the internal fabrick of this animal, the microscope will, after a dextrous dissection, discover to you the heart, just against a round hole near the neck, which probably is the place of respiration; the heart may be seen to beat near a quarter of an hour after dissection. ^a Its guts are green (from the herbs it eats) and curiously branched over with fine capillary white veins. This creature, how contemptible soever it may seem, hath a compleat sett of the same parts and organs with other animals, as heart, liver, spleen, stomach, guts, veins and arteries.

If the head be cut off, a little stone will be found, said to be of a diuretic quality, and of singular service in gravelly disorders.

They have a mouth like a hare or rabbit, and teeth as represented in fig. 175. whereof A B C shew the upper jaw, which is white, and of a semicircular form; the lower black part C D E, hath several prominent parts or teeth F F F, but all fixed together so as to compose the same bone. Mr. Hook observed this very snail (of which the figure now before us is a picture of its teeth) to feed on the leaves of a rose-tree, and to bite out half-round bits of the size and shape of the letter C.

I

If

^z Nat. Delin. p. 148.

^a Power's Obs. p. 38.

If a snail be suffered to creep upon a bit of glass, you may by the naked eye (but better if you apply the hand-glass of your microscope to view it through) observe a little cloudy stream passing from its tail to the head, that never returns the same way; and this as long as the snail is in motion.

Of the scales of fishes.

THE outside coverings of fishes are scales, formed with inconceivable beauty and regularity; some longish, some round, some triangular, some square, and some or other of all the variety of shapes imaginable: some again are armed with sharp prickles, as those of the perch, soal, &c. others have smooth edges, as the cod-fish, carp, tench, &c. There is likewise a great variety even in the same fish; for the scales taken from the belly, the back, the sides, the head, and all the other parts, are very different from each other.

The scale of a soal fish is delineated, as it appear'd in the microscope, at fig. 176. whereof C D E F represents that part of the scale which shews itself on the outside of the fish, and A B C D, the part which adheres to the skin, being as it were furrowed, that it might hold the faster, ⁱ each of which is terminated on the outside by pointed spikes, and every other of these much longer than the interjacent ones.

Mr. Leeuwenhoek supposes these scales not to be shed during the whole life of the animal; but to have an annual addition of a new scale growing over the old one, and extending every way beyond its edges, in proportion to the fishes growth: somewhat in the same man-
ner

ner as the wood of trees enlarge yearly by the addition of a new circle next the bark; and as the age of a tree may be known by its number of ringlets; so in fishes the number of plates ^k composing their scales, denote to us their age.

To prepare scales for the microscope, take them carefully off with a pair of nippers, and wash them very clean, and place them in a smooth paper, between the leaves of a book, to make them dry and flat, and then place them in sliders between the talcs for examination.

The eel, snake, viper, lizard, slow worm, and the eel, &c. afford a great variety of scales. The dog-fish scales consist of a great number of horny points, which appear in the microscope to be curiously ridged or carved.

Of spiders.

THERE are so many different sorts of spiders, and their form so generally known, that a description of them in this place, cannot be expected. I shall therefore proceed to describe some of those particulars of this creature, that are only to be discover'd with the assistance of the microscope.

Some spiders have six eyes, others eight, others fewer, and some more. They all seem to be creatures of prey, and to feed on other small insects, but their ways of catching them are very different. The shepherd spider by running on his prey; the hunting spider by leaping on it; other sorts weave nets, or cobwebs, whereby they ensnare them. Nature having equipped them both with materials and tools, and taught them how to work and weave their nets, and lie perdue, and to watch diligently, and run on any fly, as soon as ever entangled.

I 2

Their

^k Leeuwenhoek's Epist. Phy. Epist. 24. Mai, 1716.

Their eyes are immoveable and transparent, but not pearl'd; they are situated in a most curious manner, and deserve the strictest examination.

The way to view them is to cut off the legs and tail, and bring only the head part before the microscope, upon a glass slip or slider, or to stick them upon the point, or pinch them between the nippers, and so apply them to the microscope.

They have all eight legs, and two arms, or shorter legs near their mouth, that assist in taking their prey; they are beset thickly with hairs, have each six joints, and end with two hooked claws, ferrated, ¹ or having teeth on their inside, whereby they cling fast to any thing; and may be often seen to hang down from the branch of a tree, on a thread of their own making, assisted by the help of these claws.

Fig. 177. represents part of the leg of a spider; B, C, D, shew the two extreme claws armed with teeth like faws; E, the third that hath no teeth. It is certain, that when the spider does not wind itself by its thread upwards, but runs along its web, it then takes hold of the spun thread with this third claw. This spider had eight eyes, two of which were on the top of the head, to see what passes before him: below these two others, which look strait forwards; on each side of the head were two more, the two foremost to see collaterally before him, and the two hindmost to see backwards.

Fig. 182. represents that part of the head which contain'd the eyes separated from the membrane in which it lay. P Q, the eyes that look upwards; K L, those that look strait forward; I M, those that look sideways forward; H N, those that look sideways backward. They have no eye-lids, but are fortified with a hard, polished, and

and transparent crust : as these eyes are immoveable, nature hath indulged them with so large a number, to give them information of any thing that any ways concerns them.

Every spider is furnished with a pair of forceps, represented at A B, and C D, fig. 183. in the fore-part of its head. They stand horizontally, and when not made use of, they let the claw of them fall down on their respective branches, like a knife clasped upon its hilt, as at C D, and there they lie between two rows of teeth, that are likewise employed to hold fast its prey.

Authors are divided in their opinions on the poison of spiders, some calling these forceps stings; as Mr. Leeuwenhoek, who calls the hooked claws A B and C D stings; and says, that towards their extremity at B and C, are two small holes, from whence, according to all appearance, when it strikes its enemy, it therefrom ejects a liquid matter, we call poison.

He put a frog and a spider together into a glass, and having made the spider sting ^a the frog divers times, the frog died in about an hour's time.

Dr. Mead believes this to be a mistake, and that while the spider bites, a short white proboscis ^a is thrust out from the mouth, which infills a liquor into the wound.

They frequently cast their skins, which are to be found in cobwebs, in which the forceps may be examined, being always shed with the skins, and easier separated than when alive. They are commonly spread out to view, and by their transparency, every minute part is seen with much distinctness.

The microscope hath also informed us of the manner how the spiders weave their webs, and of their texture, for the performance of which nature hath endowed

I 3

them

^a Phil. Transf. No. 272.

^a Mead of Poison.

them with five little teats, or nipples, near the extremity of the tail; whence a gloomy liquor proceeds, which adheres to any thing it is pressed against^o, and being drawn out, hardens instantly in the air, and becomes a string or thread strong enough to bear five or six times the weight of the spider's body; this thread is composed of several finer ones, that are drawn out separately, but [¶] unite together at two or three hair's breadth distant from the body of the spider. The threads are finer or coarser, according to the size of the spider that spins them.

Fig. 178. represents a part of the threads, which came out of two of their working instruments, and were divided from each other, just as they issue from the body; and R S T V, fig. 179. represents one of the four outermost instruments or nipples, with its quills or reeds, which put together is not so large as a common grain of sand; from whence it is easy to conceive, how small those instruments must be, and how fine the threads encased within them. At W these working instruments stood as thick by each other, as they are represented between R and S; and that part of the figure from the sight, was not cover'd with those sort of quills, but with hairs only. It is also observable, that a few of these instruments are bigger than the rest, and consequently produce a larger thread. C F, fig. 180. represents one of these between two others of the smaller sort D E and A B, one of which had a wrinkled or harled thread.

Spiders emit their eggs, not out of the hinder part of their body, as in all other animals, but under that upper part of the belly, near the hind legs, where grows a kind of hook, of a particular figure, which partly covers the aperture from whence the eggs issue. Fig. 181. represents a spider of an ordinary size, with its legs contracted,

as

^o Phil. Transf. No. 272.[¶] Ibid No. 325.

as if it was dead, in order to shew the above-mention'd aperture; and at D the hook is seen.

Fig. 184. G H I K shews the hook separated from the spider's body, as it appear'd through the microscope; between I and K are seen the wrinkles or folds, which Mr. Leeuwenhoek supposes are made to produce a more than ordinary motion: E F shews the part that join'd it to the body, and between F and G are two round balls. The use of which he could not discover.

The eggs of some spiders are a good object, being flattish at one end, and round at the other, with a depression at the center of the flattish end, and a yellowish circle round it; their colour is a blueish white like counterfeited ^a pearl; when they hatch, the little spiders come out perfectly form'd, and very nimble. They deposite their eggs to the amount of five or six hundred, in a bag strongly compos'd of their own web, which the spider either carries under her belly, and guards with the greatest care, or else hides it in some safe recess. When just hatched, the young spiders make an entertaining object for the microscope.

The current of the blood may be seen in the legs and body of spiders, as has been before hinted; many other wonders will be discover'd by the curious in the dissection and examination of their several parts.

The carter, shepherd, field, or long-legged spider, is different from most other spiders in two particulars; the first, which is only discoverable by the microscope, is the curious contrivance of its eyes; it has only two, and those placed upon the top of a small pillar, rising perpendicularly out of the middle of its back, or rather the crown of its head. The two eyes, B B, fig. 185. were placed back to back, with the transparent parts

or pupils more protuberant than the rest of the circumambient matter, * looking towards either side, but something more forward than backwards. C, fig. 187. shews the column on which they stood, and D D the crown of the head.

The second peculiarity is the prodigious length of its legs, which are eight in number, in proportion to its small round body. Each leg of this, of which the figures 185. and 186. are a representation, was above 16 times the whole length of its body; they are jointed just like those of a crab; each of which proceeds from a small shell-like case, of a conical figure, as at I I I I, &c. of fig. 186. which represents the under part of its belly; these are fastened on to the protuberant body of the insect, forming a kind of blunt cone, whose apex is at M, about which the smaller cones of the legs are placed, each of them reaching almost to the top, in so admirable a manner, as does not a little manifest the wisdom of nature's almighty architect, in the contrivance thereof. It has two fore claws K K tipped with black like a crab's, which open and shut exactly like those in a scorpion, and are saw-like or indented on the inside. Its horns are seen at A A and mouth at L.

The best way to observe this spider is to cut off all its legs, and place it before the microscope upon the object-carrying glass, or upon the black and white object-plate.

The little white field-spider with short legs, found plentifully among new hay, whose body appears like white amber, embossed with black knobs, out of each whereof grow prickles like whinpricks, some have six, some eight eyes, that may be distinctly seen, quick and lively;



Of the King and Emperor of a Bee

My eye has a royal blue pupil, clear and
brilliant, surrounded by a pale yellow circle.
The surrounding or burning liquid, which is not
yellow and large, has two tails or branches
which, together with the green
of surrounding all over this animal, afford a
distant prospect for the microscope.

A red line or line often found upon
the wings, much like a sword, with a
long and small head and about the
length of the body, extending along the
side of the head, they all fall off and drop

the wings, and several pairs of
wings, which are the legs of

Of the King and Emperor of a Bee

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brilliant, surrounded by a pale yellow circle.
The surrounding or burning liquid, which is not
yellow and large, has two tails or branches
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brilliant, surrounded by a pale yellow circle.
The surrounding or burning liquid, which is not
yellow and large, has two tails or branches
which, together with the green
of surrounding all over this animal, afford a
distant prospect for the microscope.

Of the Sting and Scraper of a Bee. 121

lively; each eye has a violet blue pupil, ¹ clear, and admirably surrounded by a pale yellow circle.

The wandering or hunting spider, who spins no web, but runs and leaps by fits, has two tufts of feathers fixt to its fore paws, which, together with the great variety of colouring all over this animal, affords a beautiful and delightful prospect for the microscope.

There is a red mite or louse often found feeding upon spiders, in shape much like a tortoise, ² with a little head, and six long but small legs; and about the legs of the field-spider they cling exceeding close whilst the animal is alive, but when dead they all fall off and creep away.

Mr. Bon hath made several pair of stockings and gloves, from a silk ³ wound off from the egg bags of short legged spiders.

Of the sting and scraper of a bee.

AS the contrivance and structure of the stings of most insects are nearly alike, they will be sufficiently understood by a description of that of a bee, as discovered by the microscope.

A bee's sting is a horny sheath or scabbard, that includes two bearded darts; this sheath ends in a point, near the extremity whereof a slit opens, through which at the time of stinging, two bearded darts are protruded beyond the end of the sheath, one whereof being a little longer than the other, fixes its beard first, but the other immediately after; they penetrate alternately deeper and deeper, taking hold of the flesh with their hooks till the whole

¹ Power's Micro. Obs. p. 13. ² Power's Micro. Obs. p. 19.

³ Phil. Trans. No. 325.

122 *Of the Sting and Scraper of a Bee.*

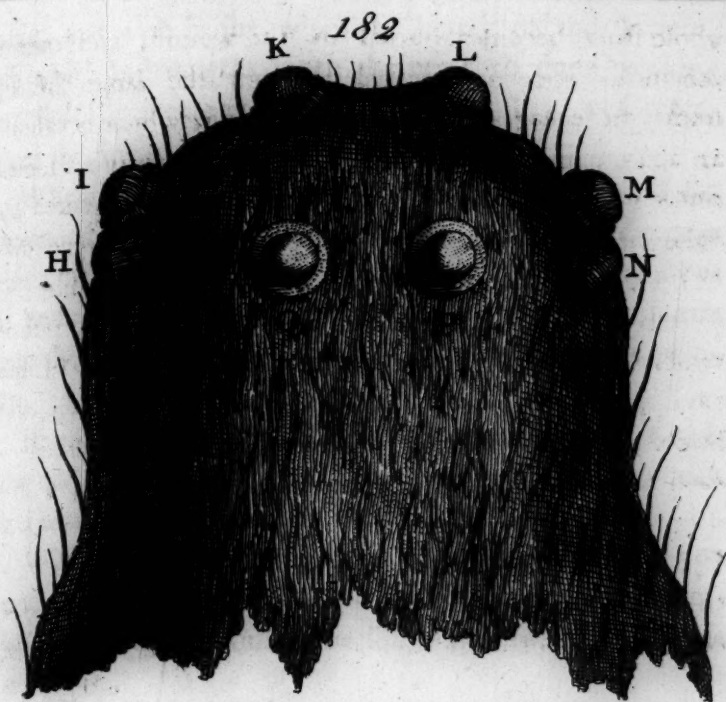
whole sting becomes buried in the wound, and then a venomous juice is injected through the same sheath, from a little bag at the root of the sting, which occasions an acute pain, and a swelling of the part continues sometimes for several days after. This is best prevented by enlarging the wound immediately to give it some discharge, and anointing it with a little common oil.

A B C, fig. 188. represents the sheath or case, out of which the two stings or rather spears are protruded. ^v E the cavity, in which they lie. C the thickness of the case below; and about C, A, the two spears shew themselves each in a separate place. Fig. 189, shews part of the sting taken out of the sheath, K its edge or bearded part, L its back without beards. M N, fig. 190. represents the whole sting taken out of the sheath with its back that is without beards next the eye; the upper part M O is inclosed round about and hollow within, the lower part O P open; P N shews part of the broken nerve, Q R is part of the body fasten'd to the sting, and placed in the thicker part of the case D C A, fig. 188. A B C, fig. 191, represents both the darts as they lie together close against the sheath ^z; yet one of them with its point a little before that of the other, to be ready (as I conceive) to be darted into the flesh. And fig. 192. shews both the darts in part out of the sheath; and one a little higher than the other, as if it were at work.

Fig. 193. represents one of the two arms wherewith Mr Leeuwenhoek thinks the bee makes her honey-combs, and are furnish'd with three peculiar joints as at D, A, B. Fig. 194, is one of the scrapers placed on the fore part of the head, by which she scrapes the wax from flowers. Fig. 195. is the wiper placed forward on the
heads

^v Arc. Nat. Tom. iii. Epist. 133. Phil. Trans. N^o. 97.

^z Derham's Phil. Theo. p. 240.





[Faint handwritten text, possibly a signature or date]

head, and with it she wipes the honey off the flowers; all which instruments when the bee hath done working are skilfully sheathed under her head. Fig. 196 represents the scraper of a wild bee.

When the darts are struck deep in the flesh, if the wounded person starts before the bee can disengage them, she leaves her sting behind in the wound; but if he has patience to wait until she withdraws the spears into their scabbard, the wound becomes much less painful.

If you divide a bee, especially an humble bee, ^a near the neck, you will see the heart beat most lively, which is a white pulsing particle.

Within the yellow plush or fur of humble bees you may frequently find a small whitish very nimble animal, ^b not much unlike the shape and form of a cheese mite.

The way to view a bee's sting with the microscope, is to cut off the end of its tail, and then touching it with a pin or needle, it will thrust out the sting and darts, which may be snipt off with a pair of scissars and kept for observation; or if you catch a bee in a leather glove, its sting will be left therein, being unable to disengage its hooks from leather: and when it is quite dead, which it will not be till after several hours, you may quite extract it with its darts and hooks; by squeezing the tail, pulling out the sting ^c, and pressing it at the bottom you may likewise push up the darts; but without some practice this will be a little difficult.

The poisonous juice may easily be found in the bag which contains it; and by letting the bee strike its sting upon some hard body, enough of the said juice may be obtained

^a Power's Micro. Obs. p. 4.

^b Ibid p. 20.

^c Power's

Micro. Obs. p. 4.

obtained to put upon a slip of glass, in order to view the salts floating therein at first, and afterwards shooting into crystals; or if you gently squeeze its tail, you may perceive a drop of this diaphanous liquor at the very end of the sting, which if wiped off will be immediately renewed.

The stings of scorpions may be examined in the like manner.

The poison of vipers has also been viewed by the microscope, but for a description of this I shall refer the reader to Dr. Mead's Essay on Poisons.

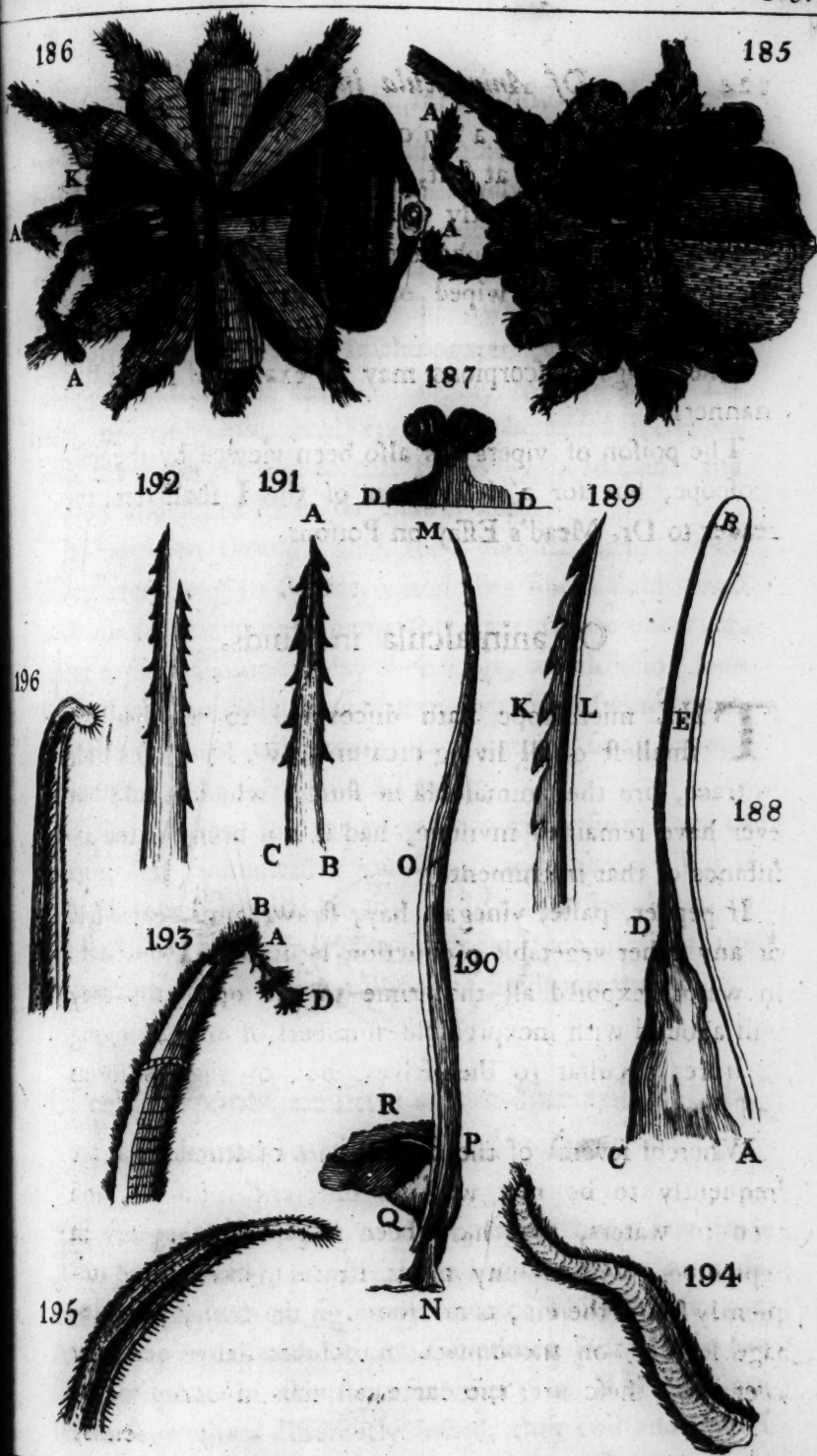
Of animalcula in fluids.

THE microscope hath discovered to us that the smallest of all living creatures, we have been able to trace, are the animalcula in fluids, which would for ever have remained invisible, had it not been for the assistance of that instrument.

If pepper, paste, vinegar, hay, straw, grass, oats, &c. or any other vegetable production be infused a few days in water, exposed all that time to the open air, they will abound with inexpressible numbers of minute living creatures peculiar to themselves, but of various forms and sizes.

Whereof several of the same species of animalcula, are frequently to be met with in different infusions, and even in waters, that have been exposed, especially in September, without any mixture; such have been frequently found therein, as are found in the cavity of a cabbage leaf, or on the dipsacus^d, &c. and that certainly several of these are the same animals under different forms,

^d Phil. Trans. No. 284.



forms, such a regular process being observed in them, and constant uniformity in their appearance, makes it probable that most of them are produced from the spawn of some invisible volatile parents, and generated like gnats and several other sorts of flies, which are bred and undergo several changes in the water before they take wing; that some of them originally may be water insects, or really fish, small enough to be raised in spawn with the vapours, and to fall down again in rain, and to grow and breed in water that is kept.

It has been thought that these minute flies, which hover every way in the air, when they find a fluid stored with convenient nourishment for their future offspring, resort to it in swarms to lay their eggs, which being soon hatched, the animalcula produced therefrom swim about, and live happily, till grown to a certain size, change their forms, take wing and fly away.

If the infusion is covered only with a fine lawn or muslin, few animalcules will be found therein; but if it stands open it will be full of life in a few days: in the least drop taken from the surface of such infusion, the microscope will discover millions of living creatures.

Of eels, serpents, or little worm-like animalcula,
found in vinegar and paste.

IF vinegar be exposed to the open air but a few days in hot weather, it will abound with eel-like animalcula, represented by fig. 197. two of which are seen at A, making equal undulations, sometimes four or five are seen to move in the same manner; at B B B B, are shewn four others differently coiled, they coil and uncoil themselves with a surprizing swiftness, at C is a representation

sentation of one with a forked tail. Monsieur Joblot saw but one of these in 35 years observation: * however, the solar microscope seldom fails of discovering some of them every observation. That marked D, although its mouth seems different from the rest, is not so, but owing to its not being represented in the same position. They are to be applied to the microscope by taking up a drop of the vinegar on a pin's head, and placing it upon a hollow glass slip or slider. When this drop begins to evaporate, their motion will be considerably retarded, at which time their mouths may be seen, and many other particulars may be observed in them.

Some people have imagined, that the sharpness of the vinegar, is occasioned by the eels striking their pointed tails against the tongue and palate; but it is very certain that the sourest vinegar hath none of those eels, and that its pungency is intirely owing to the pointed figure of its salts, which float therein.

Animalcula in the shape of eels are often found in many infusions but of a different size.

Dr. Power observes, that if vinegar, in which these eels abound, be but moderately heated, † they will all die, and sink to the bottom. But cold does not hurt them, for after such vinegar had been expos'd a whole night to the severest frost, and was frozen and thawed, and frozen again, and so several times over, they were as brisk as ever: he also tells us, that he put some vinegar full of these eels into an essence glass, and poured thereon about the same quantity of oil, which floating on the vinegar, all the eels would constantly creep up into the oil,

* Joblott's Obs. p. 2. Imprimé à Paris. 1718. † Power's Micro. Obs. p. 34.

oil, when the vinegar began to freeze, but when it thawed, they as constantly returned to it again.

To furnish yourself with minute eels, always ready for the microscope, boil a little flour and water, till it comes to the consistence of such paste, as the bookbinders and shoemakers use; expose it to the air in an open vessel, and to prevent its hardening, or becoming mouldy on the surface, beat it well together whenever you find it tends that way; after a few days it will turn sour, and then if it be examined with attention, you will find thousands of those eels on the surface thereof. To preserve them all the year, you need only put a little water to them, if the paste grows dry, or a supply of other paste, always observing to keep the surface in a right condition, which will be easily done when it is once stored with these animalcula. Their continual motion will prevent any mouldiness thereon.

Apply them to the microscope upon a glass slip or slider, first putting on it a drop of water, taken up upon the head of a pin, for them to swim in, and if the paste be thick, it must be diluted with a sufficient quantity of water to disentangle the eels, and render them distinctly visible.

They are very entertaining objects, but more particularly so if examined by the solar microscope, with which they may be magnified to an inch or more in diameter. The internal motion of their bowels may be very plainly seen, and their mouths open to a considerable width.

Of animalcula in several cold infusions of whole pepper.

B, D, K, H, O, R, L, fig. 198. exhibits the first sort of them, each having several little spots more transparent than the rest of their body. The regularity of the figure, under which these animalcula generally appear, and the rapidity of their motion, prevents us from discovering on what part of their body their head is placed, but after a little time we are enabled to do it, although they continue in motion; for when the drop of water in which they swim, is grown thick by the insensible evaporation of its subtle parts, it gradually retards the motion of these minute fish; and affords us sufficient time to observe many things, that will teach us to admire the creator's wisdom, even in the smallest part of these minute creatures.

You may then perceive that as two of these animalcula are advancing forward, one moving along the line from A to B, and the other from C to D, in turning about the first follows the dotted line B E, and the second moves from D to F.

You may also frequently see that of two of these animalcula, one of them will run as it were along the line G H, and the other over that of I K, leaving a small space between them, yet too little for a third L, to find a passage, which thus inclosed between them, rushes forwards to save himself in the direction of the dotted arch towards M. Others after having moved along a straight line, as H G to O, turn about so swift upon a point at O, which is their head, that their oval figure appears almost circular, after which they launch out with an extremely swift motion towards P. Others

also

also having run along a line as Q R, and as it were turning upon their own center at R, describe several circles, then shoot forwards with an extraordinary swiftness along the line S T.

Fig. 199. represents another sort of animalcula, whose head is adorned with hairs, and motion generally circular, called *copple crown*^a. A third sort represented at fig. 200. called a *silver bag-pipe*^b. A fourth sort is a kind of water spider, with its mouth open, as at fig. 201. Two of them are represented at fig. 202. conjoined and turning upon their common center. Fig. 203. shews two more of them also coupled as they swim in a straight line. Another sort is represented at fig. 204. in some measure resembling a weaver's shuttle; its hinder part is tufted with hairs, which assist him in swimming. Fig. 205. exhibits a swarm of exceedingly minute insects of different sizes and shapes, which serve for nourishment to the larger sorts.

Of white pepper.

Infusions made of whole white pepper, produce finer animalcula than the foregoing, but not in so short a time. The large bag-pipe of this infusion advances and recedes by turns, as if swims before the microscope; and just before the water is totally dried, a great number of eggs may be seen within them, and in the next moment they will all be dried up, and appear like a confused mass.

K

Of

^a Joblott's Obs. p. 14.

^b These names were given to the animalcula of the several infusions, by Mons. Joblott, who endeavour'd to call them after the common names of things and animals, to which these animalcula bore some resemblance; which resemblances, I apprehend, in some cases arose from the lively imagination and hasty determination of Mr. Joblott.

Of long pepper.

LONG pepper put whole into common water, produces animalcula no less surprizing than the two foregoing; in this is sometimes found an animalcule somewhat like a caterpillar; and a different sort of eels from those found in vinegar and paste, being thicker and shorter than they, but do not live near so long.

On repeating these experiments at different seasons in the year, and in different years, other sorts will be found not here represented.

Take common black pepper grossly pounded, and put it into a glass vessel, as much as will cover the bottom thereof, about half an inch thick, on which pour about three or four times that depth of rain or river-water; shake and stir the pepper and water well together at first, but afterwards not at all, and expose the vessel to the air uncover'd; in a few days a little skin may be seen on the surface of the water, which, examined by the microscope, will be found to contain millions of animalcula, at first scarce discernable, but continually increasing in bulk, till they arrive at their full size. Their numbers too increase prodigiously, till at last the whole surface of the fluid seems alive.

This experiment will succeed in winter, if the water is not frozen.

The animalcula represented by fig. 206. are very common, and are described by Mr. Leeuwenhoek, who hath seen the tails of some of them nine or ten times longer than their bodies,¹ which are about one third of an hair's breadth, but in general they are four or five times as long. In moving they commonly twitch up

their

¹ Phil. Transf. No. 284.

their tail into a screw-like form, as at b, fig. 206. and this spring is so strong, that when the tail is entangled, as it frequently is by the extremity, they bring back their whole bodies by the jerk and convulsion of the tail, which quickly returns to its first straitness. When they lie still, they thrust out and pull back again a bearded tongue, and a current constantly runs towards them, occasioned probably by the motions of some fins or legs too fine to be discerned.

Those animalcula exhibited by fig. 207. abound in all waters, and are largest of all; their length is about an hair's breadth, and three or four times more than their own ^k; they are very thin and transparent, and turn themselves very quick, shewing both back and belly; their edges are adorn'd with a great number of minute feet seen chiefly at the two extremities; at one end there is a kind of brush resembling a tail; they are swift in motion, and by their turns, returns, and sudden stops, seem to be continually hunting for prey. a represents one of them on its back; b one on its belly; at c and d, is seen how they often appear in other positions.

There is generally another sort of an oval shape, as at fig. 208. a b c, lengthening and shortening themselves as occasion requires, and sometimes two of them may be seen conjoined, as at a.

Another sort are a kind of capillary eels, they wave their bodies but little, move equably and slow, and swim as well backwards as forwards. See fig. 209.

Several kinds of mixtures put amongst them, while they are before the microscope, produce different effects. The smallest drop of spirit of vitriol, upon the point of a pin, being put to them, they immediately tumble down dead; dissolved salts kill them, but with this difference,

K 2

instead

instead of being flat, as in the former case, they shrink into oval forms. Tincture of salt of tartar throws them into convulsive motions, after which they soon grow languid and die, without changing their shape. Ink kills them, and so does fresh blood, urine, spittle, and dissolved sugar ¹.

There is also another sort of animalcule, frequently found in this infusion, of a spherical figure, only pointed like a pear, as at fig. 210. in which are a vast number of dark spots, in a confused agitation; they chiefly turn as it were upon a center, first one way, and then the contrary, sometimes they take a large circuit, but always with their pointed end foremost.

Another sort represented at fig. 211. is also found in great numbers; they move briskly, are very active, contracting, and dilating as they swim along; they have several feet in their fore parts very visible; when the drop of water is almost evaporated, they shrink up into a globular form, then their feet standing out, may be seen to move nimbly; a, shews them at their length, and b when contracted.

Fig. 212. represents another animalculum, not uncommon amongst the rest; its motion very nimble, always keeping its sharp extremity foremost; some are clear and ribb'd from the point to the thick extremity, others transparent only at the fore part, as at a and b.

The water which drains from dunghills, and is of a brown colour, is generally so prodigiously stored with various sorts of animalcula, that it must be diluted with water before they can be sufficiently separated, to distinguish their different kinds; one particular sort is found amongst these, which is very rarely to be met with elsewhere, and are shewn at fig. 213. their middle part dark, and

¹ Ibid. No. 203.

and beset with hairs, but both ends transparent; their tails tapering with a long sprig at the extremity thereof, their motion slow and waddling.

Of animalcula in a cold infusion of fenna.

ABout the middle of July, as much as could be taken up with two or three fingers of the leaves, stalks, and branches of fenna, was put into cold water, and in about eight days, the surface thereof was stored with extremely minute longish bodies, separate from each other, but without motion. The corpuscles represented at fig. 214. were thought to be nothing else but pieces of the bark from the branches of the fenna; but in about eight days after, they all disappeared, and a surprizing number of worm-like animalcula succeeded them, but less than the first, being alive, and swimming a little below the surface of the water; one of these worms is seen at fig. 215. Its head round at I, its body composed of eleven ringlets, the lowest extremity of which ends sometimes in a plain perpendicular to its body. At other times with three round protuberances, as at M.

Through the skin there appears a very white fibre, branching as it were from each side of the tail, in a strait line towards the head, where they unite in an arch, as at N, fig. 216. This fibre extends and contracts itself alternately, by which means the ringlets are drawn nearer to, or pushed farther from each other. Part of the water being evaporated by its standing several days, a little fresh water was poured thereon, which caused the skin that swam on the surface of the infusion to sink to the bottom of the vessel; the infusion was thereby refined, and more transparent than it was before, which occasioned

the discovery of two new sorts of animalcula, and this in the least drop that could be applied to the microscope, D, and E F, fig. 217. are their representatives. The largest of them resembles the silver bag-pipe, each having crooked heads, as at F; they have also two motions, one strait, and the other circular, slow enough to be easily observed.

Another kind of fish-like animalcula resembling a carp, is shewn at fig. 218. its motion was wriggling as the dotted line a b c d.

In January a great number of another sort were found in this infusion of Senna, which ballance themselves from right to left as they swim directly forwards. Another time, after replenishing the water, other minute animalcules that do not ballance themselves were found therein, and the same day others also so exceeding small that their form could not be discerned. A few days another sort shaped like fig. 219. its head terminated almost in a point. After this infusion had stood a whole year, another worm-like animalcule was found therein, represented at fig. 220. whereof A was its mouth, which was round; from whence issued three fibres to its forked tail B B, two other sorts, as represented by K L, fig. 121. were also seen in this infusion.

Of the water found in oysters.

A Dozen of oysters being opened, all their liquor was put in a clean drinking glass, which in the space of two hours appeared to be upon the fret, and of a fine pearl colour, and its smell like that of the sea; on applying some of this liquor to the microscope after it had stood four days, a great number of minute transparent
oysters

oysters^m in rapid motion were observed therein. a b c d, fig. 222. represents one of them, of which a is the head, their shape altered as they placed themselves in different positions before the eye; their motion was sometimes direct, at others circular. The fifth and sixth day some of them seemed to be dead; but, on continuing to observe them, were afterwards found to move with a prodigious swiftness, one going one way, another the contrary, often rubbing and stopping against each other; then being disturbed by others rushing strongly against them, altered the state of their rencounter, and directed themselves to another place; they stretch out and shorten themselves considerably, and are often seen coupled as at a and c, fig. 223. and fig. 224. Moving together from a towards b, and from c towards d, they turn much slower than those in pepper-water, and perform their circular motion much as they do, turning sometimes on their own center, and sometimes on a point near the extremity of their head. This liquor being observed near eight days, no other animals than those of the same figure could be found therein.

In fresh oyster liquor diluted with common water, were found animalcules with two moving horns in each of their heads, which formed a kind of crescent as at e, in others as at d, fig. 225. but the horns are so transparent, that they must be viewed attentively, and that for some time before they can be discovered.

On putting the liquor of six or seven oysters into a glass vessel one day at noon, the next day at seven a quantity of these minute oysters were found swimming therein, although the vessel was stopped: whence it seems not improbable, but that these animals were produced

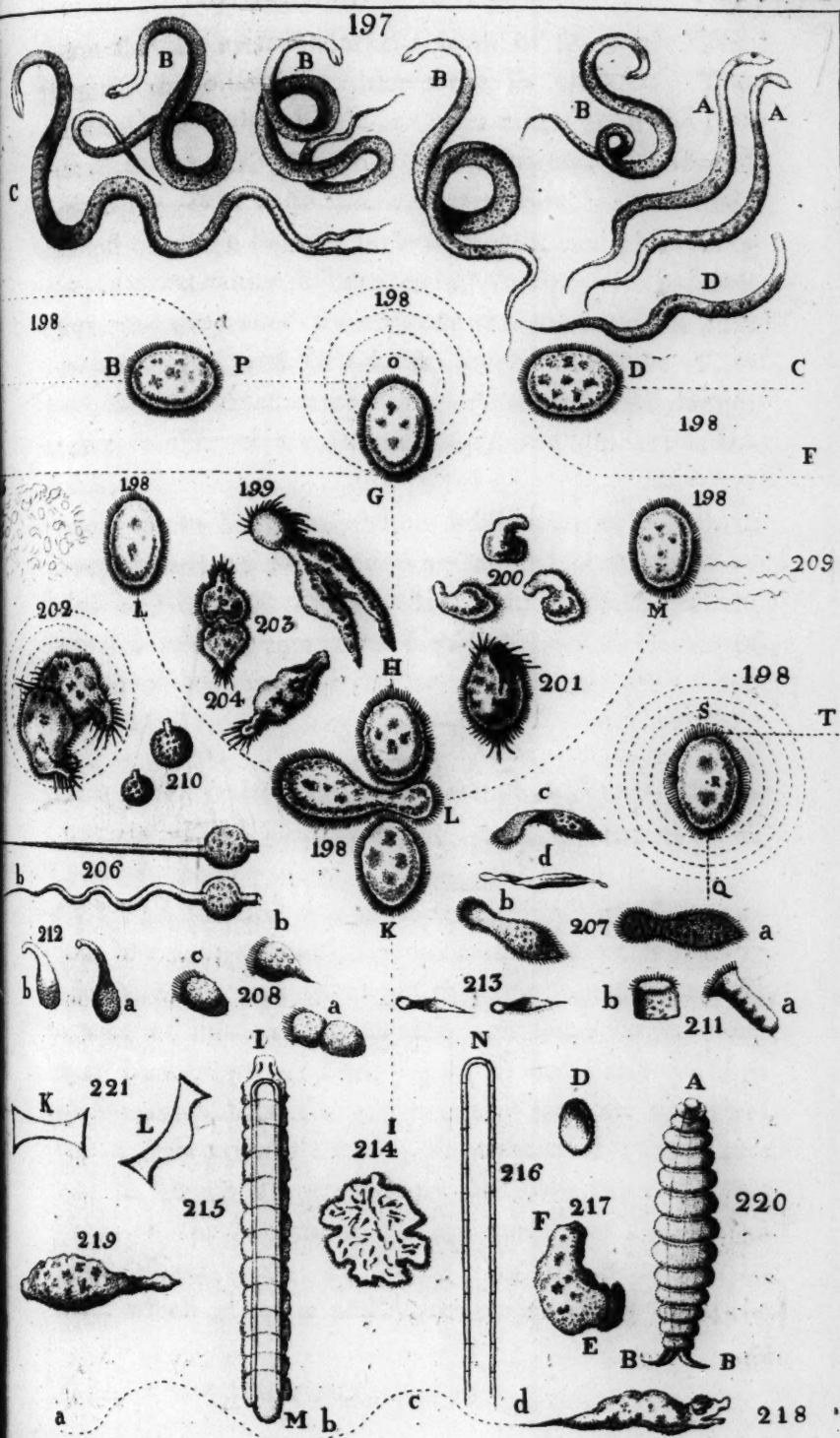
from
 K 4
 = Joblott's Observ. p. 20.

from the eggs of the oysters themselves, and that they do not proceed from other animals that either fly or float in the air. Six days after two different sorts of new animalcula appeared in the same liquor; the first are represented at fig. 226. it stretches itself out and shortens itself alternately. The second sort is seen at fig. 227. which moved so slow that the following particulars were observed; it had four short legs near its head, and five longer behind. In the same liquor was also found another sort represented at 228.

In other fresh oyster liquor were also found different animalcules, as represented at i, l, m, n, o, p, q, fig. 229. m exhibits a worm with a sharp head and round tail. Those at n and o shew two of the same worms joined together, the strongest dragging along the weakest. At p is seen one of another figure, and at q are two smaller, holding each other by the beak and swimming in company.

Of an infusion of pinks made in common water both cold and hot.

SOME pinks, not quite blown, being steeped in cold water, produced living animalcules, which upon examination with the microscope were found to be of the shape represented by fig. 230. On the sixth day appeared a larger sort, but fewer, being very transparent, and strewed with little spots, fig. 231. The eighth day the larger sort appeared finer and longer than before, and moved after a different manner; in fifteen days the surface of the liquor was covered with little white worms, somewhat below which was a prodigious number of minute animalcules. The twenty-eighth day a large worm





worm shewed itself under the form of fig. 232. The forty-eighth some eels, like those in vinegar. The fiftieth day a little white worm was taken upon the surface of this water ^a, its body so transparent, that several little white fibres were discovered therein, the two middlemost of which being a little separated, and proceeding from the extremity of the body, run parallel to each other, and are united by an arch near the head: it hath two black eyes, and two hooks in the fore part of its head, as represented at fig. 233. At G of the same fig. is seen another of a curious form, found also in this infusion.

Some pinks being infused in boiling water, which in eleven days time swarmed with animalcules, but very small, and on the fifteenth day were not to be found, only some worms might be seen on the surface thereof with the naked eye.

Of a cold infusion made of a nosegay, composed of pinks, roses, and jessamin.

THIS infusion was made the eleventh of May, and the nosegay cut into pieces for the better placing it in the vessel, and in about three or four days a great number of minute animalcules, and some larger ones, were found therein; their figures, colour and motions are so various, that it would be a task too long to undertake a description thereof. Nevertheless I cannot pass over in silence an animalcule that was found in this liquor on the beginning of September. It consisted of three distinct parts, fig. 234. The first part A is its head, which advances and retires by jerks. B, the trunk
of

^a Joblott's Observ. p. 28.

of its body, and C its tail, it is of a transparent white, and often draws its tail in, at the end of which are two black hairs D D.

Of an infusion of blue-bottles.

THE stalks of a large nosegay of blue-bottles with some of the flowers, were put into cold water on the second day of June, and at the same time some of the flowers by themselves were put into a glass of water; in twelve hours time the microscope discovered several animalcules of the form of fig. 235. in a small drop of this liquor. And the next evening four other sorts, very transparent, of an oval figure, unequal in size, and different in their motion. The fifth of the same month, another sort of the shape of fig. 236. appeared therein; and on the sixth a new sort, A B C, Fig. 237. with an oval head and a tail, which terminated in a point, being five or six times longer than its body. On the seventh day, one of these last was observed to drag after it a bunch of the sediment of the infusion, which sunk to the bottom of the concave, upon which the drop of liquor was placed for observation. It is very pleasant to behold so small an animal endeavouring to pull this bunch about, which he is scarce able to move, as at I, drawing himself back, and wriggling its tail, as at M. Sometimes five or six of these animalcules may be seen fastened by the tail, to a great bunch of this sediment, that sticks to the bottom of the object carrying glass, drawing themselves nearer to, and retiring farther from it by turns. During this exercise, they change their first figure, and recover it again alternately; and as their tail is naturally strait, as at I, they endeavour to drag the lump after them in a right line.

It is remarkable, that extremely hot weather kills them, and in five or six days they are succeeded by others.

We have no reason to doubt, but these minute animalcules are furnished with eyes, for two of the same figure are often seen to approach each other without touching, and then turning, with a prodigious swiftness about their own center.

Another sort is sometimes found in this infusion, whose extremities are terminated by two plane surfaces, parallel to each other, as at fig. 238.

An infusion of tea:

HAVING put into the tea-pot as much tea, and a sufficient quantity of boiling water, as would make six large cups, on the fifteenth of July; the tea-leaves which remained after the hot infusion, were put into a large glass jar, filled with spring-water, and exposed to the open air for about ten days; after which, in the least drop that could be taken up, when applied to the microscope, were found a swarm ° of exceedingly minute animalcules, of a round figure, moving slowly. Some days after they were fewer in number, but increased in size, clearer, much more distinct, and of an oval figure, as at fig. 239. the circumference of their body appeared black, but all the rest perfectly white and transparent, and now swam with a surprizing swiftness. Their bodies were of so delicate a consistence, as that their natural figure was preserved for the space of two or three minutes after they were dead.

The

The twenty-third of September, three other sorts of more minute animalcules were found in this liquor, and some of the eel-kind also.

An infusion of raspberry-stalks.

THIS infusion is one of them which does not cause a disagreeable smell, nevertheless it produces in about twenty-four hours time, the finest ^P animalcules that are to be met with in fluids, and in as great numbers. Their representation is at o o, Fig. 240. they are at first very white and transparent, but more so in some place than in others, with little marks upon them, and at length this whiteness changes into a transparent yellow colour. They may be seen stretching out and shortening themselves from oval to round, by means of obstacles which they find in their way. They are often seen to hold each other by the beak, and in that posture they move exceeding fast, without quitting their hold, as at P. Another sort of animalcule was found in this infusion, of the shape represented at Q; between the middle of its body, and the head, was a transparent substance, regularly beating, but so quick, that the shape of it could not be discerned,

Infusions of fennel, sage, melon, four grapes, stalks, and leaves of marigolds.

FENNEL, with its large and small stalks, was put into cold water to infuse, August eleventh and on the thirteenth following, in the smallest drop that could possibly be taken up, and placed upon the object carrying
glass,

glass, might be seen a swarm of an almost innumerable quantity of little animals, represented at fig. 241. amongst which were others of a round figure, and about five or six times longer.

The twenty-second of August, some sage leaves were infused in cold water, and retained their natural smell all the time of the infusion, which was about twelve days; nothing was seen in this liquor but some little animalcules^a that appeared no bigger when magnified, than a grain of millet does to the naked eye; and an infinite number much smaller, that when magnified, appeared no bigger than the smallest dot that can be made upon paper, with the finest pen, and a little below the surface of the liquor, was found three very small but white worms.

The twenty-eighth of September, in a drop of this infusion, was found two sorts of minute animalcules, represented at fig. 242.

The twenty-second of August, some barberries were put into cold water, which produced animalcula of the shape of T, fig. 243. in twenty-four hours time.

The twenty-fifth of the same month, a bit of the rind of a melon, with a little of the pulp, and a few of its seeds were put into cold water; the next morning appeared some fine transparent animalcules, whose form is shewn at V, fig. 243. Many little white longish bodies were also found therein, whose figures are seen at X; and other less bodies marked T, without any sensible motion.

Some four grapes were also infused in cold water, on the fourteenth of August, and on the twentieth, a great number of animalcules appeared therein, but so exceedingly minute, that their shape could not be distinguished; on the twenty-fifth two sorts presented themselves, one

as small as the last; the other at Y, fig. 244. The fourth of September these little animalcula were exceedingly multiplied and increased in size, some of them were joined together in the form of a figure of 8, as at P, fig. 244. and moved sometimes circular and sometimes in a right line; on the eighth of September were found upon the crust, which swam upon this infusion, some minute worms, and also in a drop of the liquor a considerable quantity of other eel-like animalcula.

On the 25th of August, some of the stalks and leaves of marigolds, were put to steep in cold water, and eight days after there was three sorts of animalcula found therein; the first is represented at Z, fig. 245. the second at R, of the same figure; and the last, for which there was no room in this plate, were of the eel-kind, different from those in vinegar, and different also from those in paste.

First infusion of new hay in cold water.

THIS infusion stood but twenty-four hours before it was filled with life, and at the end of five or six days, in the most minute drop of this water, five or six sorts of living animalcula were discoverable; different in colour, size, figure, and motion.

The smell of this infusion is very strong in hot weather, but decays as the infusion grows old; animalcules are very rarely to be met with in any other infusion that are larger, finer, more transparent, or that live so long as those found in this.

The second infusion of new hay.

THE 4th of October some new hay being put into cold water in two different vessels, one of which was stopped close with a piece of vellum, made very wet, and the other left open: two days after, three sorts of animalcula were discover'd in each infusion, and also a sufficient quantity of them: this experiment is a proof, that those animalcules were produced from eggs, which had been deposited by their parent animals upon the hay, and also that they were not wasted thither in the air.

The 10th of the same month, more of these animalcula were found in one drop of that infusion, which had been covered, than could be seen in the like quantity not covered.

The third experiment made upon the same hay.

THE 13th of October some of the same new hay was boiled in common water, above a quarter of an hour, and an equal quantity of it put into two vessels, nearly of the same size, one of which was immediately cover'd, even before it was cold, and the other left open, in which was found some animalcula, at the end of a few days, and not one in the infusion, which had been covered; * after which great care was taken to keep it close for a considerable time, to try if there were any living animalcula therein, but none could be found, at length it was left open, and in a few days, some animalcules were found therein, which determined that these animals

* Joblott's Obs. p. 39.

‡ Ibid. p. 40.

mals proceeded from the eggs of their parent animals, waisted thither in the air, since those which had been brought there in the hay, were totally destroy'd by its being boiled in water.

A composition of several infusions mixed together in one vessel.

TAKE equal parts of an infusion of senna, of raspberry stalks, and of hay, &c. mix these all together, and half an hour afterwards take as usual a small drop of this mixture, which being put upon the object carrying glass, and placed before the microscope, will give you the pleasure of seeing in this little drop, the animalcula of all the infusions you have mix'd together. * And here it is proper to take notice, that all these different animalcula cannot subsist long in this mixture, each being desirous to remain in its first infusion, therefore all sorts of infusions are not proper to afford the pleasure of this sight, for they ought to contain in them something upon which the animals can subsist.

An infusion of rhubarb.

RHubarb is a purgative drug, and must be a long time infused in water before any animalcula can be found therein, or any disagreeable smell, for in about five weeks there was found only one sort of animalcula, which does not merit a particular description; we shall only say that the mixture of a drop of this infusion, with as much of that of senna, does not destroy the animalcula in either; and that at the end of fifteen days the animalcula in the infusion of rhubarb * were all dead.

Of

* Joblott's Obs. p. 40. * Ibid p. 48.

Of an infusion of mushrooms.

A Large mushroom being infused in cold water, produced from one day to another an astonishing multitude of infinitely small animalcules, of a round figure, which appear'd in a microscope that magnified twenty-five thousand times, of the same size that a grain of rape-seed does to the naked eye ^y.

The third day some of a larger size were found therein, with a crooked neck, and very transparent; soon after a third sort was discovered of an oval figure, and fluttering motion.

Of the little flowers of different colours that are found in meadows.

IF some of these flowers, when they are just blown, be put into cold water, in a few days a particular sort of animalcule will be found therein, resembling the sole of a shoe, one of which is represented at fig. 246. Its motion is slow, and its head directly under the letter A; it inclines itself towards B and C, stretching itself out, and contracting alternately; sometimes all its body appears as round as a bowl, at which time the surface thereof is uneven: their body is marked with longish spots, and is so transparent, that all their intestines, and the peristaltic motion may be distinguished, which are a very agreeable sight. ^z These larger sort appear at the beginning of the infusion, but at the end of fifteen days a great number of those represented at fig. 247. were seen therein, which is contrary to what generally happens in other infusions, where the smallest appear first.

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Of

^y Joblott's Obs. p. 48. ^z Ibid p. 49.

Of an infusion of sweet basil, which smells like
citron.

THREE sorts of animalcules shew themselves in a few days after sweet basil hath been infused in common water; the first are seen at A, fig. 248. the second at B, and those of the third sort almost like that represented at C. This last swims in a spiral line, folding and unfolding its body every way.

A, B, C, fig. 249. represents the animalcules found in the infusion of new hay, the colour of one, and figure of the other, was the occasion of calling one golden, and the other silver bag-pipe. That sort represented at D E, are called clubs; the head whereof is seen at D. These animalcules extend and contract, twist and untwist themselves several ways.

Infusion of blue-bottles.

FIG 250. represents a new sort of animalcula found in this infusion of blue-bottles. A shews the head, B its tail, C D its breadth, which seems divided throughout its whole length by a curved line, drawn from B towards A; that part of the body marked C, seem'd to be filled with several little globules, less transparent on this side, than on that marked D; the neck of this animal, which is very long, shortens itself from time to time, as does also the hinder part, marked B^a. It swims extraordinary slow, and does not live upon the object-carrying glass above five or six minutes, but two of these were discovered in five or six drops, and the second,

^a Joblott's, Obs. p. 51.

cond, fig. 251. was something different from the first, for its body B C was furnished with little globules, that render'd it less transparent than the first was, at A B and C D.

Infusion of old hay.

IN this infusion were two sorts of animalcules that merit a particular description. The least is seen at fig. 252. it was of a transparent white; A its head, B its forked tail, with which it pushes itself forward; and it swims so steadily that no particular motion of its body can be discerned.

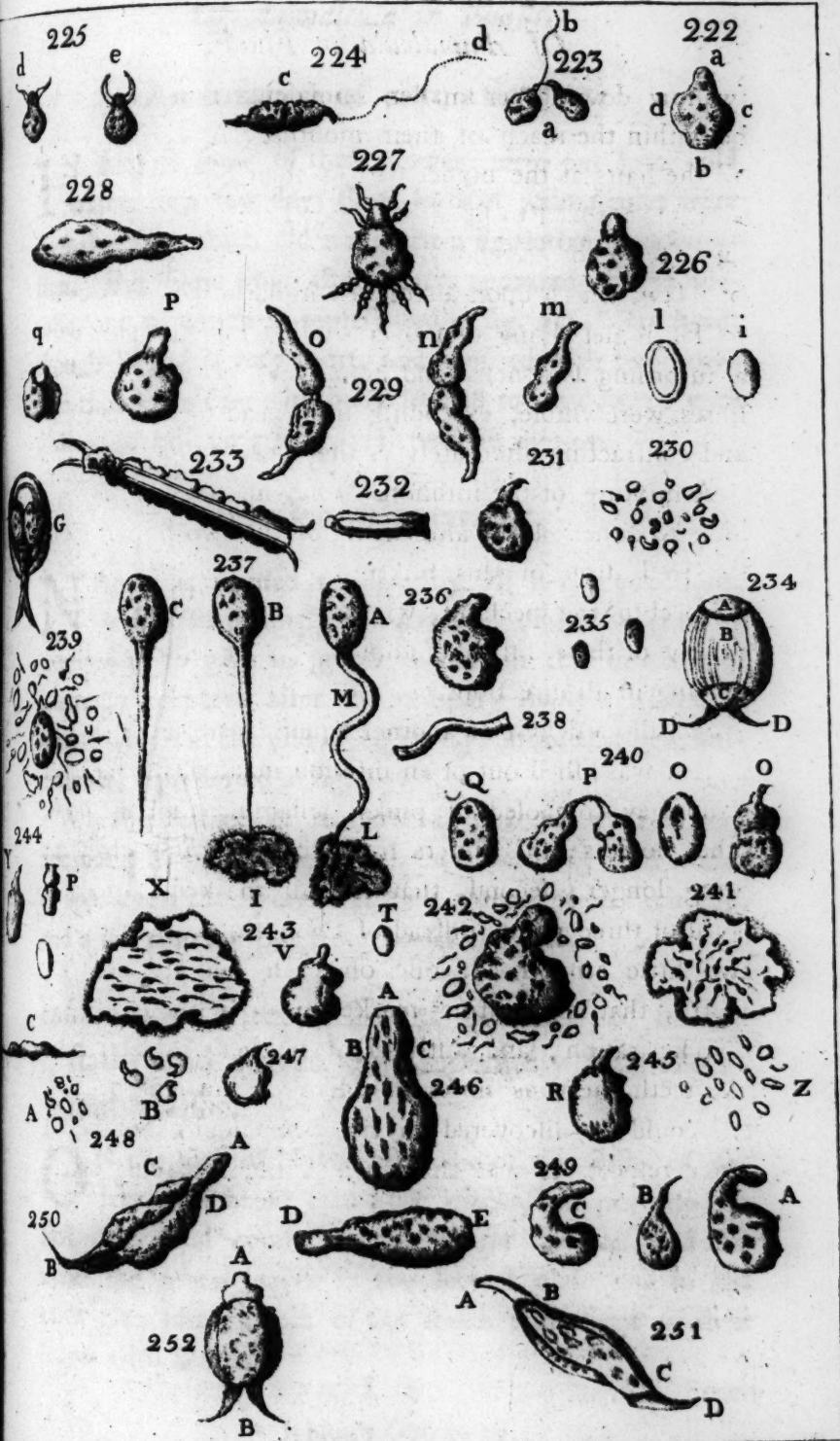
The second sort, are more extraordinary and surprising, as well in size as other circumstances; two of them are represented at fig. 253 and 254. marked A, C, D, B, and A C E F B; A shews the head, B its forked tail, C its heart, which may be seen in a regular motion, and D its intestines. It is called an aquatic caterpillar; there are two different colours of them, one of a transparent white, the other of a pale yellow. In moving on the object-carrying glass, they first fix the points B, and then extending their body as much as possible, rest the fore part upon another place, and draw up the hinder part, and then again fix the point B as before, and so on; they also fix the points of their tail to the object-carrying glass, and stretch out and retract themselves by jerks, and sometimes turn round about upon the point B, at other times they spring forwards with a sudden jerk, and swim about for some time.

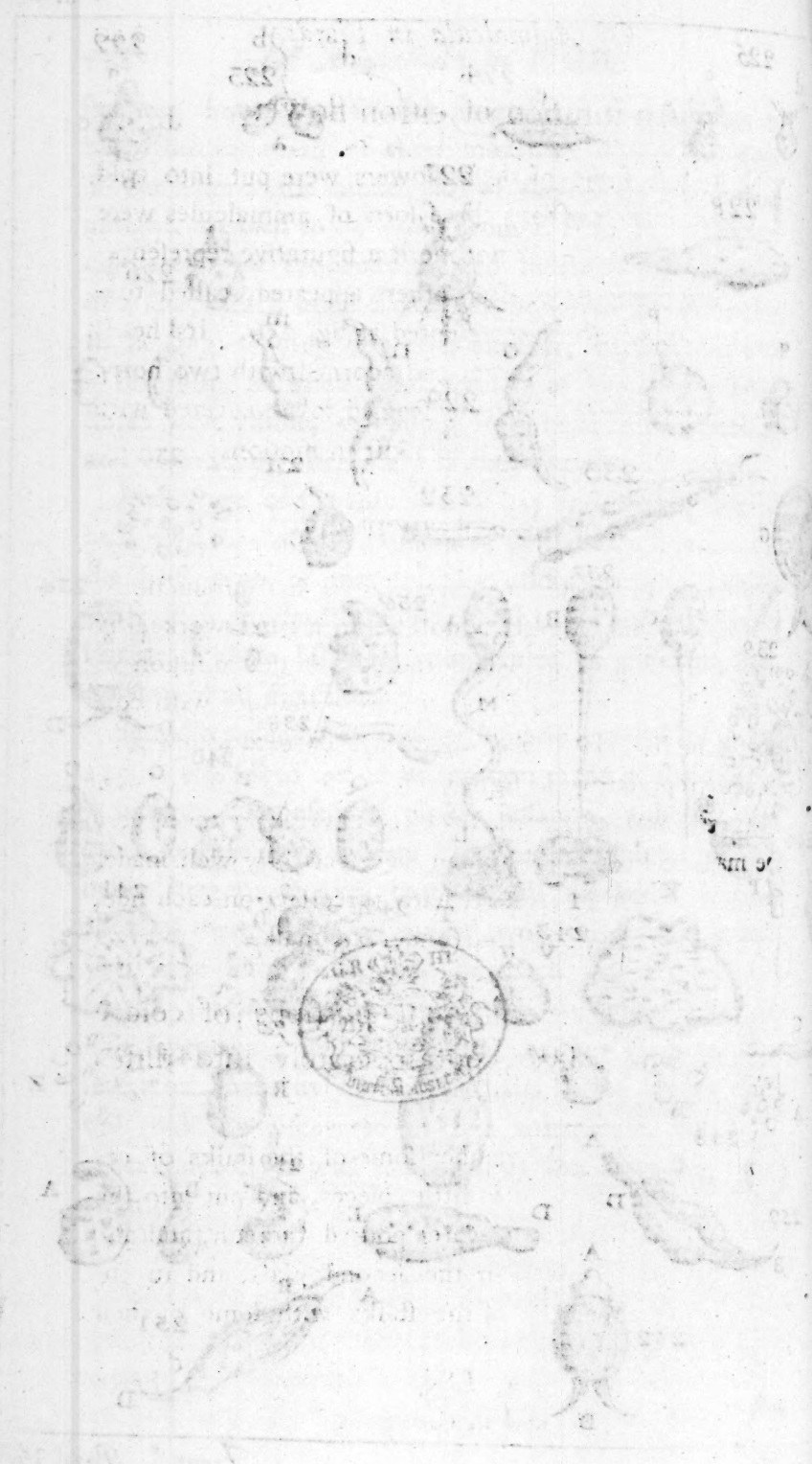
When they rest themselves, they commonly open their mouths very wide as at A, fig. 254. its lips also are furnished with hairs, as expressed in the figure, which move very quick; it is really surprising to see how hastily they

swallow down other smaller animalcula that happens to be within the reach of their mouths. At certain times all the hairs at the hinder part of their body which stand upright, are seen to lie down from E F to B. The circumference of the body seemed indented like the teeth of a saw, which upon a closer examination was discovered to be ringlets lying one over another, coming out with a surprising swiftness, and sometimes even the nervous fibres were visible, extending from head to tail, swelling and contracting alternately as they crawled along.

A mixture of the infusions of hay and celery, does no hurt to either of the animalcula of the two liquors; but the least drop of this mixture affords a very pleasant prospect to the spectator, who will in an instant discover variety of these fish-like animalcules of different sorts, moving in all directions.

See also a design of another aquatic caterpillar at fig. 255. it was fished out of an infusion made of the stalks of a nosegay composed of pinks, jessamin, tuberoſe, and other flowers; this differs from the foregoing: first, in being longer; second, that its tail marked I, is composed of three points instead of two; third, that it hath two little arms L M, one on each side its heart a; fourth, that its intestines marked b are without any visible separation; and lastly, that neither ringlets, saw-like teeth, nervous fibres, nor hairs in the length of its tail could be discovered in this animalcule, but in all other respects it was the same as the foregoing caterpillar.





An infusion of citron flowers.

IN August some of these flowers were put into cold water, in a few days three sorts of animalcules were seen therein, which did not merit a figurative representation. But some time after others appeared, called tortoise, one of which is represented at fig. 256. Its head, though large, is very short, and adorned with two horns like those of a deer: its body seemed to be covered with scales, its tail very long, and swift in motion.

Infusion of anemony.

Nature is pleased to diversify all her productions, and is surprisngly admirable in all her works, by continuing to give us proofs thereof in this infusion of anemony prepared after the ordinary manner with cold water, which at the end of eight days afforded a new animalcule, represented at fig. 257 ^b.

All the surface of its back ~~is~~ covered with a very fine mask in form of a human face, perfectly well made, as appears in the figure. It hath three feet on each side, and a tail coming out from under the mask.

Infusions of three different portions of celery stalks and leaves, put seperately into different glasses.

ON the first of November some of the stalks of celery were broke into little pieces, and put into the first glass, and common water poured thereon, and also upon the green leaves in the second glass, and in the third glass some pieces of the stalks with some of their leaves with water.

L 3

Seven

^b Joblott's Obs. p. 57.

Seven days after these preparations, some animalcules were found in each of them, two sorts in the first, and but one only sort in both the other: but in about a month's time all the three infusions contained ten different sorts both in shape and size.

Those of fig. 258. and 259. are the smallest; but in number they exceed all the other; when coupled they resemble a figure of 8, as at a, fig. 259. These also are called bag-pipes; they couple by the beak, which is a little crooked and sharp, and notwithstanding this coupling they swim very fast, diving to the bottom of the drop of liquor which is placed upon the object carrying glass, and rising up again to the top thereof alternately; they separate from, and approach each other, without intermission. These bagpipe-like animalcules are not entirely alike; but there is in these, as in all other animals, different sorts of them.

Some of them swim alone with a surprising rapidity, while others advance with a moderate swiftness, some go very slow, and others rest quiet for a long time together; but the greater part of them are in a perpetual agitation; some of them are long, some short, others as white as silver, some of a golden colour, and others brown.

It is a singular curiosity to observe what passes upon the surface and all around the circumference of a mass of matter which hath formed itself into a very little bit of thin skin, so small, that the best eyes are not able to see it without a microscope: they are found by chance on the surface of the infusion, and are generally fastened to the end of the stalks. If a bit thereof be taken out with the point of a pin, and placed upon the object-carrying glass before the microscope, there will be seen swarms of all these animalcules we have been speaking of. There are such great numbers of them moving with so much celerity,

celerity, that it is troublesome to turn the eye upon a sight so new and surprising. In certain places thereof there are seen some differently coupled. Others also, that rest themselves, and keep the watch as soldiers do, which seem apprehensive of being surprised; whilst others go out a good way from the mass as though they would make some discovery, then they return again as if they had something to relate to those which kept the watch, and this is seen all round the mass.

In another drop, taken from another place of the same vessel, has been often seen another new and curious sight, viz. that sort of animalcula which are long and flat, called soles, and are represented by A B C D, in fig. 260. The sides of this animalcule are very sharp; the head and all the rest of its body is transparent, except a few brown spots which appear within. The different postures, and the variety of motions observable in these animalcula, cause more pleasure in beholding them through a microscope, and greater satisfaction than can possibly be imagined by reading the most particular description of them.

In the glass where only the leaves were infused, there were amongst others some animalcules like those expressed at E, F, G, fig. 261. at one end of these figures may be seen a considerable opening which is their mouth, and appears sometimes round as at F, and sometimes ovalish as at E and G; at other times it is so firmly closed as not to be discovered. It swims by jolts, and ballancing from right to left, conducting itself in appearance by a circular motion of its head. It also changes its figure by folding, unfolding, and suddenly rolling itself up in the form of a ball, and then alternately stretching out again very quick into its natural state.

There is another sort of animalcula that appears to have neither head nor eyes, and are represented at H I K,

fig. 262. their body ends in a long transparent tail, and motion generally very slow. They are frequently observed to have a bit of the skin (which is formed on the surface of the infusion) sticking to their tail as at L, sometimes they drag it after them, at other times it happens to stick to the object-carrying glass, at which time they draw themselves back on a sudden towards it, and then stretch out again very slowly.

In the least drop that could be taken up from the third glass, wherein the leaves, stalks, and roots were mixed, was such an infinite number of those little animalcula represented at fig. 258. that they could scarce find room enough to pass between each other.

There was also a large oval animalcule, as at M N, fig. 263. its head could not be distinguished.

In a second infusion of the leaves of celery was a new animalcule, represented at fig. 264. its head is seen at O, and is beset with long hairs that move alternately, its motion is slow and figure uncertain, appearing sometimes under the form of a bag-pipe, and at others, under that of a cross.

• Fig. 265. represents another sort of animalcule of a spheroidical figure; another sort at fig. 266. and others like fig. 267. this last moves with a surprizing velocity, and frequently turns itself upside down.

Amongst other infusions of celery, was found an animalcule in the shape of a bottle, as at fig. 268. Fig. 269. exhibits another sort of the bagpipe-like animalcules, two of which are seen at P, differently coupled from any of the foregoing.

Lastly, at fig. 270. is represented a most extraordinary animalcule, almost round, its body covered with hairs, and motion circular,

Of infusions of straw and the ears of wheat.

IN the beginning of March, some wheaten straw, and two ears of wheat were put into cold water, the second whereof produced animalcules of the shape of fig. 269.

Others also were found therein, represented at fig. 271. its mouth is seen at A, the inside of its body was filled with a quantity of little white and brown transparent corpuscles.

A third sort is represented at fig. 272. turning according to the order of the letters A B C, and moving slowly, its colour like that of unpolished silver, strewed with little brown spots. Its head is seen at A, tail at B, and back at C.

Another sort of animalcule is seen therein of an oval form, and one called a golden bottle, represented at fig. 276. its mouth is sometimes fixed to a round body, to which it strongly adheres, as at fig. 273.

Another sort called soles, contracting and stretching themselves out as they swim along, which is very quick, are represented at fig. 274.

See also another sort, at fig. 275. their mouth is at A, which is sometimes extended to a great width. B C is the tail.

Fig. 277. represents an animalcule with a swan-like neck. A is its head, B its tail, and C its body. They are of two sorts, one very transparent, and the inside of the body of the other brownish. Their intestines may be seen in motion.

The animalcules S and T, fig. 278. are those which were before called water-spiders, or rather greedy guts, from

from the quantity of other minute animalcula they swallow.

That represented fig. 279. is the only one of its sort found in the infusion of wheaten straw. Its figure is like a purse, its mouth large, and here represented open; but when it stretches itself out for swimming, it is so neatly shut, as to enclose its horns.

Fig. 280. exhibits an animalcule, called a little sole; and at fig. 281. and 282. are two others that move extremely slow, and are thousand times smaller than an hair^c.

Fig. 283. represents a worm-like animalcule, composed of a great number of very small spiral rings, whose extremities are terminated in very long, and exceeding fine points.

Of aquatic pomegranates.

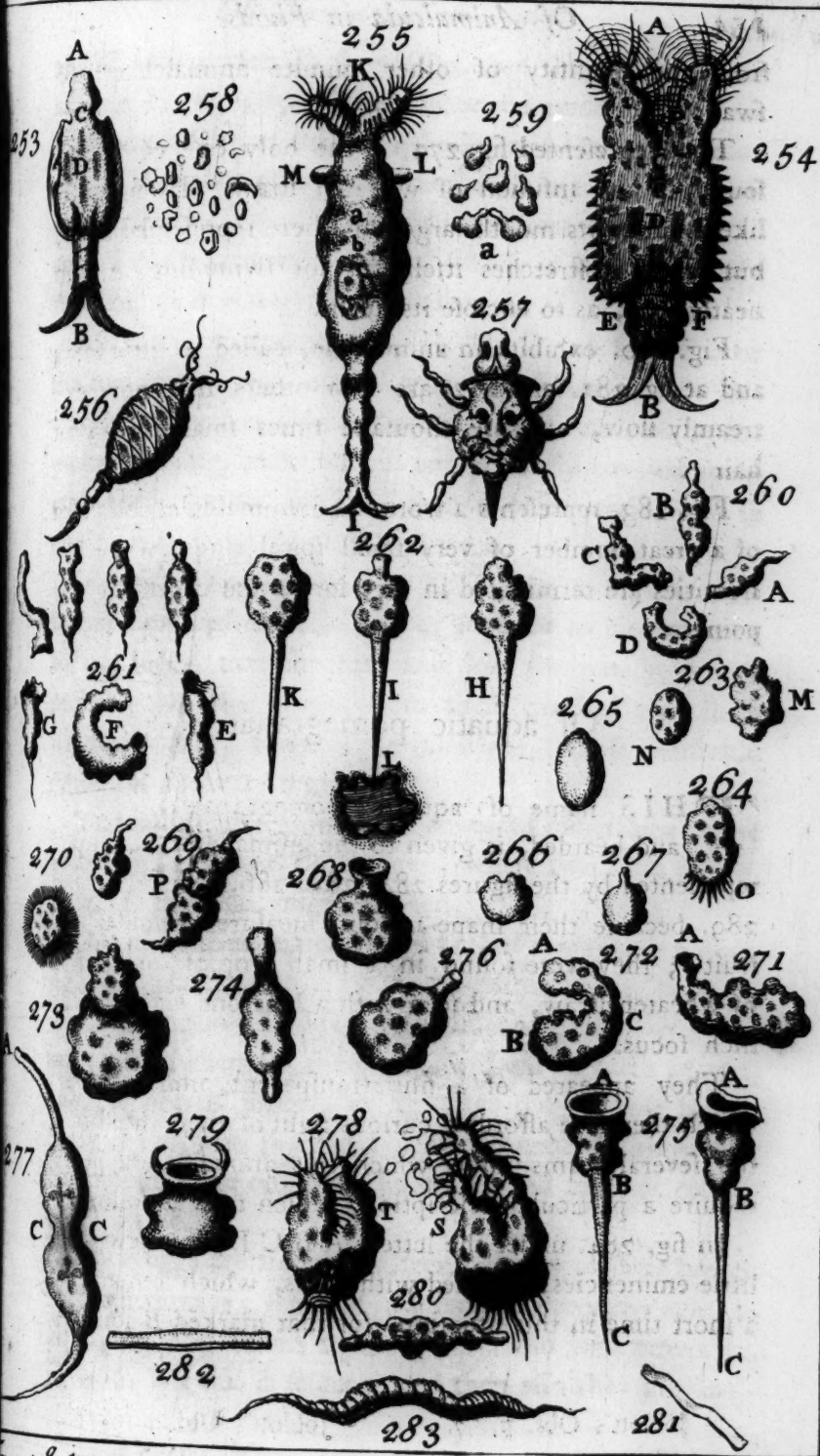
THIS name of aquatic pomegranates, crowned and bearded, is given to the animalcula, which are represented by the figures 284, 285, 286, 287, 288, and 289. because their shape in some measure resembles that fruit^d; they were found in a small drop of an infusion of wheaten straw, and seen with a lens one eighth of an inch focus.

They appeared of a fine transparent amber colour, which therefore affords a curious sight of their intestines; the several forms under which this animalcule appears, require a particular description, which take as follows:

In fig. 284. under the letters A B C D, are shewn four little eminencies, adorned with hairs, which remain but a short time in this situation, for that marked B joins A, and

^c Joblott's Obs. p. 67.

^d Joblott's Obs. p. 68.



and C unites with D so closely, that they then appear as at A D, fig. 285. These increased eminencies, form the separated lips of this animalcule, and the regular motion of the hairs with which they are adorned, obliges all minute bodies, at a small distance from these lips, to enter into its mouth. Part of which is also as strongly repelled, as it was greedily swallowed.

All the protuberances A, B, C, D, of fig. 284. or the two of fig. 285. contracting themselves a little towards E, discover a sort of crown, with four points, represented at fig. 286. which are presently covered again with these eminencies, and then exposed again, and so on.

In each of these figures, at E, is seen a regular pulsation, supposed to be its heart; it seems to be embraced by two lobes, that separate and join alternately, which probably are the lungs; from these proceed two little ligaments at G, towards the intestines, whose peristaltic motion is also very regular.

The tail of this animalcule appeared sometimes round and close, at other times open, when two little points, as at H, fig. 284. might be seen.

One of these animalcules had four of those sharp points, fig. 287. placed two on each side the anus; between which a long tail I L is protruded, and drawn in again with great swiftness: the end L, in some of these animalcules, appeared forked, as fig. 285. the tail can be entirely drawn into the body, at which time the rings that compose it, slide one over the other, and cause it to become opaque.

Their eggs are frequently seen fastened to their breech by small threads; some of the females carry but one, as at M, fig. 289. others two, fig. 285. and some others six, fig. 286. but this is seldom, and then also they are smaller.

ler. They rub their eggs with their tail, which as it enters into, and goes out from the body, turns from one side to the other with a great deal of pliability; those eggs which are full, appear hanging down, and are very regular and bright, those that are empty are seen quite flat, and of an oval form, and more transparent than the others, and although empty, their mothers carry them almost always fastened to their breech, as at fig. 286. Two of these eggs were seen in the body of one of these animalcules, and appeared as at G G, fig. 288.

These animalcules are a delightful object for the microscope, particularly when they tumble over head and tail, because they do it dextrously. Some turn themselves circularly, as much on one side as the other, and about the point F, which is the center of gravity of their bodies.

Infusion of the bark of an oak.

SOME of this bark being put into cold water, the fifteenth of December, and examined several times for the space of a whole year, during which time the following animalcules were discovered. The first was called a tortoise with an umbelical tail, fig. 290. This insect stretches out and contracts itself very easily, sometimes assuming a round figure, which it does not retain above a moment; then opening its mouth to a surprizing width, forms nearly the circumference of a circle; its lips are furnished with hairs, whose motion is very pleasant, because it obliges some of the adjacent little bodies, to precipitate into its stomach, where that which is fit for food remains, while the other is repelled with great velocity; its motion is very surprizing and singular.

Fig.

Fig. 291. is another sort of animalcula with an umbellical tail, differing only from the former in having its mouth fixed, and tail without any separation.

Fig. 292. represents another of the same sort, altho' under a form somewhat different; the top of its head is double, and two prominencies appear thereon under the form of horns, which were intirely covered in the other.

That represented at fig. 293. is called a water-rat, its head well shaped, and lips adorned with long hairs.

Another sort at fig. 294. is called a crab's claw, because of its two crooked beaks, whose motion as well as that of its body is very slow, its body is adorned with a great number of shining globules.

Fig. 295. is called a club, its head large in proportion to its body, which ends in a point, the inside of which is strewed with little grains both transparent and opaque.

That sort exhibited by fig. 296. is called a silk-worm's bag, because its body is composed of several rings and longitudinal fibres, the shape of its head is so nearly like that of the tail, that it can only be distinguished by its swimming.

The animalcule, fig. 297. is called a spheroid, its head is seen at A, a little below which may be seen its heart regularly beating; and several round bodies of different sizes, which probably were its eggs.

There are in this infusion several sorts of eels, different amongst themselves, and different also from those found in vinegar.

Fig. 298. represents one of them very thick with respect to its length, which was stored with a considerable number of exceeding small fibres, and others also that ran spirally from near its head towards the tail.

At fig. 299. is exhibited another kind of eel-like animalcula of great vivacity.

Another of a larger size is also represented at fig. 300. that had been dead for some time, when by chance a little eel^e was discovered fluttering very much to get out of the belly of its mother, but not being able to do it, at last died therein.

This observation is a sufficient proof that the eggs of these eel-like animalcula are hatched in their mother's body.

Fig. 301. represents an animalcule, called a weaver's shuttle; it swims smoothly, having in the middle of its body several little corpuscles resembling eggs.

Fig. 302. is called the beak of an halbert, its head ends in a point; the other extremity of its body is like a drop, and upon the throat are several long hairs.

Fig. 303. is called a water-spider; it is of a spherical figure, with several brown parallel lines, between which are some spots browner than the rest of their bodies.

Fig. 304. is called a drop, its body uniform and transparent, its neck long, but a little crooked.

Fig. 305. is called a slug, its head is round, tail sharp, body large in proportion to its length, and becomes so short in motion as to appear pretty regular.

Fig. 306. is called a water caterpillar, they are found of different sorts, and in several infusions of plants; it has been before observed, that the hairs, of which we have elsewhere spoke, are planted on the two lips of this caterpillar, which seem to turn at certain times like the rowel of a spur.

Fig. 307. is called the great aquatic spider, its figure somewhat ovalish, mouth a little sunk, which appears some-

^e Joblott's Obs. p. 76.

sometimes to reach to the middle of its body, its lips are adorned with hairs in motion, which seem to have a communication with a little part that probably may be the heart, and lungs surrounding it; its hinder part is also furnished with hairs that form a kind of tail; a little above the anus is a brown spot, supposed to be the excrement; the rest of their body is generally stored with little regular corpuscles.

This sort of animalcule is also found in infusions of wheaten straw, in that of barley mixt with some of the ears; in Turkey corn, Indian cane, in the wood and bark of acaias, or in that of whole pepper, &c. All these different sorts of water-spiders, have hairs round their body, inclining a little from their head towards their tail, and may be seen with a lens of one twelfth part of an inch focus.

Fig. 308. is called great mouth, because its mouth takes up about half the length of its body; its upper lip is much longer than the lower, and are each adorned with little hairs; its inside is filled with darkish spots, and hinder part terminated with a singular tail.

Fig. 309, A B C, is named a funnel, and is here represented under three different forms, in the middle one the mouth is open and round, the inside of its lips are adorned with little hairs, which have a quick motion; the inside of its body strewed with many little irregular spots, and its long tail generally drags after it little pieces of skin fasten'd to its extremity. The second is seen at A with its mouth shut; and the third at C, whose body is rounder, and its tail at certain times twisted in the form of a cork-screw.

Fig. 310. hath a head like clover grass, and a forked tail; its mouth very small and round.

Fig.

Fig. 311. is called a sock, the inside of its body is adorned with several transparent spots, which appear like eggs.

At the time this infusion was intended to be thrown away, it was thought proper to put a drop of it upon the object-carrying glass, and to examine it by the microscope, whereupon one of the most particular of all the foregoing animalcula was found therein. It is a kind of water caterpillar, and so scarce, that no more than seven or eight could be found in many trials during three days. Fig. 312. shews three representations of one of them; in that exhibited by A B, its body is seen to be composed of several ringlets, that enter one into the other, as the animalcule contracts itself; it pushes out of its mouth a snout composed of several pieces sheathed in each other, which are shewn at A C and D. The extremity of this snout appears to be perforated in some positions as at D; it is sometimes split in two parts, at other times into three, as at A, where they form two or three little protuberances. At L L are seen two lips furnished with moveable hairs. In other positions not one hair can be seen. While these things were observing, a kind of horn F, was suddenly protruded from its breast: its whole length appear'd to be composed of several furbelows of unequal thickneses, which go one into another like the drawers of a pocket telescope: at its tail are two very sharp points as at B E, and in some particular positions it appears in three parts as at I.

Infusion of the bark of a young oak.

ABOUT the twenty-fifth of December several little pieces of the bark taken from off a branch of young oaks were put into cold water, and in two hours after

after some of those animalcules called silver bag pipes were seen therein; and on the fifteenth of January, in a very small drop, was seen several new ones. Some of them Mr. Joblott called caterpillars, others stockings, stirrup-stockings, &c.

Those represented at fig. 313. are called golden caterpillars, being of an amber-colour; the longitudinal fibres are seen from one end of its body to the other, between which are little irregular globules.

Fig. 314. is called a stirrup-stocking; at C is a great opening which changes its shape every moment, and appeared to be its mouth; the lips were sometimes so extended as to serve it for a rudder to steer its course; its body was beset with extremely small hairs.

That represented at fig. 315, is in the form of a fishing-net.

Fig. 316. is another, of which the part G H resembles an ill-shaped leg; the middle of its body appeared to be tied with an invisible ligature.

Fig. 317. is called a club, its mouth intirely close, and body shaped like one; several little globules were seen within-side, supposed to be eggs.

Lastly, at fig. 318. is one of another kind of the bottle sort, which swam amongst the preceeding ones; and also a great number of other sorts, which do not merit a description. The cold weather increased so fast, that in fifteen days time all the animalcules in this infusion were destroyed.

Of some other larger aquatic animals.

THE waters every where are stocked with life, which makes the subject endless for the employment of the microscope; seas, rivers, ponds, ditches, and

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almost

almost every puddle, can present us with living wonders; but as these examinations have been very little attended to even by those who are supplied with microscopes, I hope these directions and the variable microscope, will be a means to whet the inclinations of the industrious enquirer, the difficulties in the use of the common instruments being here removed.

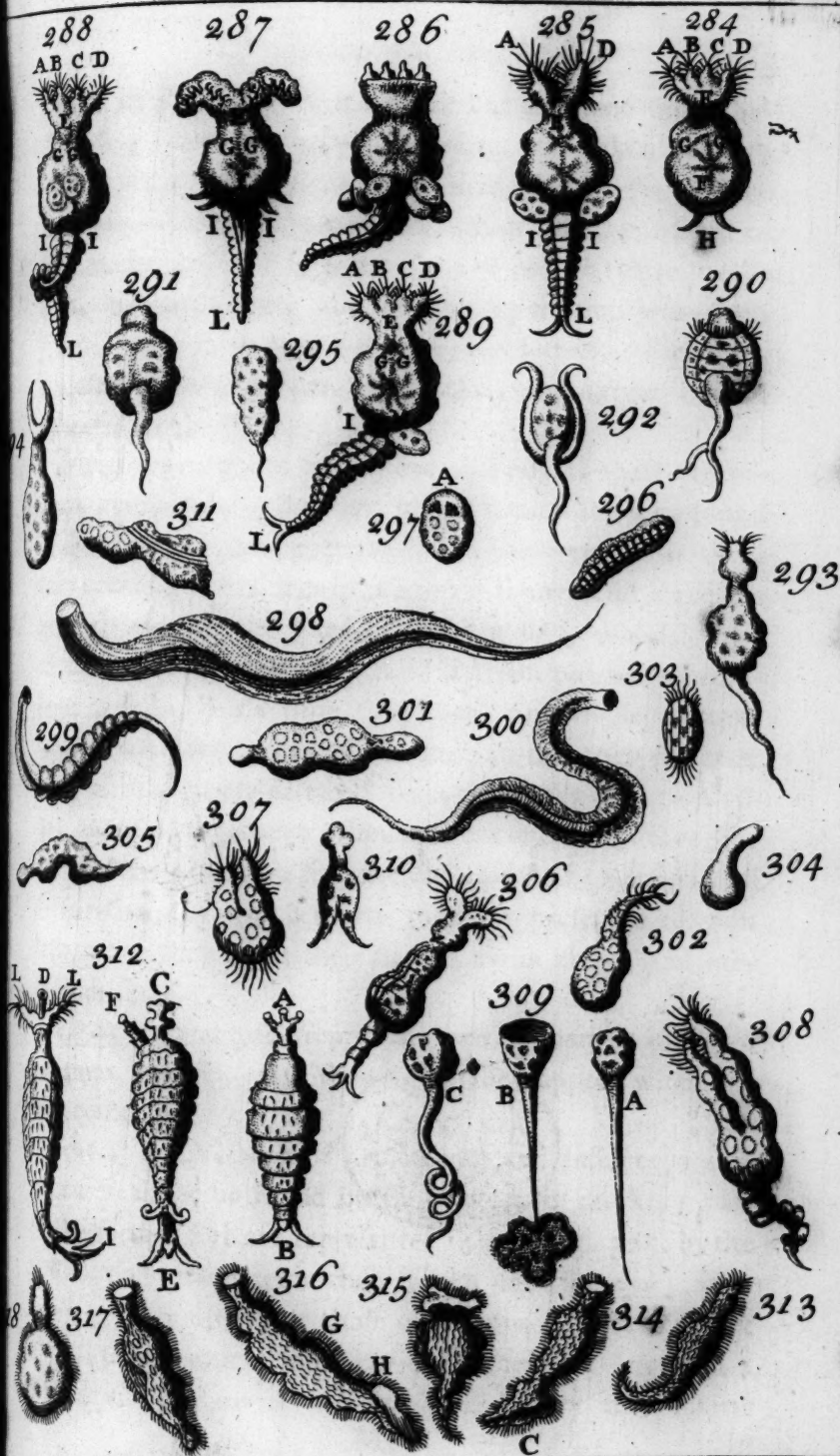
Mr. Leeuwenhoek found some surprising animalcules, adhering to the lens palustris^f; or duck-weed, which he examined in a glass tube filled with water; one sort of these were shaped like bells, with long tails, whereby they fastened themselves to the roots of these weeds. H M, fig. 319. represents a small part of the root, as it appear'd in the microscope, supposed to be almost withered and over-grown, with a great many long particles which are seen between K and L. The animalcula representing little bells, ^g are seen at I S T.

On several of these roots were observed one, and sometimes two sheaths or cases of various sizes fastened thereto by the small end: the largest is exhibited at R X Y, out of which sheath appeared a little animal, whose fore part was roundish as at X Y Z, from whence proceeded two little wheels that had a swift gyration always one and the same way, and were thickly set with teeth or notches as at P Q R S. When they have for some time exerted their circular motion, they draw the wheels into their bodies, and their bodies wholly into their sheath, and soon after thrust themselves out again and renew the aforefaid motion. Mr. Leeuwenhoek observed the case of one of these animalcules to be composed of round bubbles,^h as is represented at N, O, T. When this animalcule had thrust that part of its body from O to P,

out

^f Phil. Transf. No. 283, 295, 337. ^g Ibid. No. 283,

^h Ibid. No. 295.





out of its sheath N O, it extruded at the same time that surprising wheel-work (which before was taken for two distinct little wheels, and was here plainly seen to be but one and the same circumvolution) that consisted of four round parts P Q R S, three of which were to be seen, the fourth being almost hid; its motion was from P to Q, according to the order of the letters. Fig. 320. represents the wheel-work by itself, and larger than it appeared to the sight.

Mr. Leeuwenhoek found several kinds of these wheel-work animalcula in the slimy matter which is to be found in leaden pipes, or ⁱ gutters; when the water dries away they contract themselves into an oval figure, and a reddish colour, and become fixed in the dry dirt, which grows as hard as clay; but if to this dirt you put water, in about half an hour's time they open, and by degrees extend their bodies and swim about; and this they did after some of this gutter-dirt had been kept dry for twenty-one months together: whence he concludes, that the pores of their skin are so perfectly closed as to prevent all perspiration, by which means they are preserved till rain falls, when they open their bodies, swim about, and take in nourishment.

Fig. 321. and 322. represents two of them in different positions, and fig. 323. shews how they appear when dry and contracted.

Several species both of crustaceous and, testaceous animalcules are to be found in the waters of ditches; two of the former sort are represented in fig. 324. 325. in the posture they swim with their backs next the eye; their legs are something like those of shrimps or lobsters, but of a structure much more curious; they are less than a very small flea, are all breeders ^k, and carry their spawn

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in

ⁱ Leeuwenhoek's Arc. Nat. Tom. ii. Epist. 149. Transf. No. 288.

^k Phil.

in two bags, which hang from their sides, or under their tail, as in fig. 325. These bags are sometimes seen broke, and the spawn scattered about the water. There is a third sort amongst these as beautiful as the foregoing, but not near so large; its shape nearly resembles a shrimp, and carries its spawn as the shrimp does. These three kinds of animalcula have but one eye, and that placed in the middle of their forehead; they are often to be found so transparent, that the motion of their bowels is very plainly discovered by the microscope, together with a regular pulsation in a little part, which we may suppose the heart.

In the summer-time it is common for the water in ditches to appear sometimes of a greenish, and sometimes of a brownish colour, which upon examination by the microscope is found to consist in infinite numbers of animalcula, blended together on the surface of it, and giving it such an appearance; their shape is oval, but the middle either green or red, seems to be composed of globules, resembling the roes or spawn of fishes.

Of the fresh water polipe, with arms in form of horns; of their motion and structure.

THE nature of this insect is both extraordinary, and contrary to the general received opinions of animal life, and requires the most convincing proofs to persuade many people into a belief thereof. In order therefore to clear up this peculiar affair, I shall lay before the reader the following observations, which were made by Mr. Trembly, and also assure him, that I have repeated the major part of his experiments on this animal with the same success.

And

And first these animals were not hitherto entirely unknown, for Mr. Leeuwenhoek gives a description of a surprizing sort of minute animal, in the Philosophical Transactions, number 283. It is represented at fig. 328. as it appear'd fastened to a root of duck-weed, whilst in the water, and about three times bigger than it appeared to the naked eye; this was a large one of the sort, and had eight horns: at C is shewn a very small animalcule coming out of the other's body, supposed at first to be fastened thereto by some accident; but on a closer examination, was found to be a young one in the birth, although it had at first but four small horns; after sixteen hours its horns and body was grown much larger, and in four hours more was quite excluded its mother's body; against this on the other side appeared a little round knob, which gradually increased in bigness, and in a few hours was pointed as at D, fig. 328. About fourteen hours after it was grown much larger, and had two horns; three hours after it also fell off from its mother and shifted for itself.

An English gentleman¹ discovered one of them in some clear water taken out of a ditch; but with the utmost attention he could find no more therein. It appeared the first day as at fig. 326. but varied every moment, and the knob at a, looked like the gut cenum; two or three days after he observed some white fibres at the extremity of the knob; on the fourth it was extended at full length, and appeared as fig. 327. which then convinced him this excrescence was really an animalcule of the same species, having six horns; next day he found it separated from its mother; it is seen in its contracted state as delineated by this gentleman at fig. 329. and 330.

M 3

There

¹ Phil. Transf. No. 288.

There is a near agreement between the observations of these two gentlemen, both of them having discovered the most remarkable property of the polypes, that is to say, their natural manner of multiplying. They have also given us their exterior figure, and some of their motions; but their more surprising properties, were reserved for the discovery of the inquisitive and happy genius of Mr. Trembley. It was also known to several other gentlemen before him, but none of them discovered this remarkable re-production, which is found in the different parts of a polype after they are separated, each distinct piece becoming as perfect an animal as that of which it was only a part.

Mr. Trembley having taken notice of some plants, which he had taken out of a ditch, and put into a large glass full of water, and employing himself in considering the insects therein contained, he cast his eye upon a polype, which was fixed to the stalk of an aquatic plant, and is represented at fig. 331.

Their bodies a b are very small, and from one of their extremities at a, proceed several horns, a, c, which serve them for feet and arms, and are much smaller than their bodies. I call the extremity a, anterior, because it is the polype's head; and the opposite extremity b, posterior.

The first sort of polypes Mr. Trembley found, were of a fine green colour, and in the posture of those represented by fig. 331. The first motion he observed in them was that of their arms, which they extend and contract, bend and wind divers ways; they also contract their bodies upon the least touch, so short that they appear only like a grain of matter. They constantly turn themselves towards the light; for if that part of the glass in which they are, be frequently turned from the light, they will be found the next day to have removed themselves

selves to the light side of the glass, the dark side being quite depopulated.

For Mr. Trembley inclosed a great glass well stored with green polypes, in a paste-board box, which had a hole cut on one side in the form of a chevron, that exactly answered to the middle of the glass in which the polypes were: when this hole was turned to the light, it always happened, that the polypes assembled themselves together at that side of the glass, and also in the form of the chevron; although the glass was turned several times in this box, yet at the end of a few days the polypes were always found ranged as before. To vary this experiment, he turned the chevron upside-down, and notwithstanding this, the polypes always assembled themselves together, and in the form of the chevron, whether right or inverted.

The twenty-fifth of November 1740, Mr. Trembley cut a polype transversely (for the first time) but the head part a little shorter than the tail part, and put the two parts into a flat glass, in which the height of the water did not exceed a quarter of an inch, by which means they might be easily observed with a pretty deep magnifying glass.

In that instant the polype was cut, both parts contracted, and sunk to the bottom of the glass, like two little grains of green matter. Some few hours after both the parts stretched themselves out, and were easily to be distinguished from each other, the anterior end of the first being furnished with horns, whereas the other had none at all.

The first part moved its arms, and the next day he saw it change its place in the glass, and both were observed to extend and contract themselves for several days.

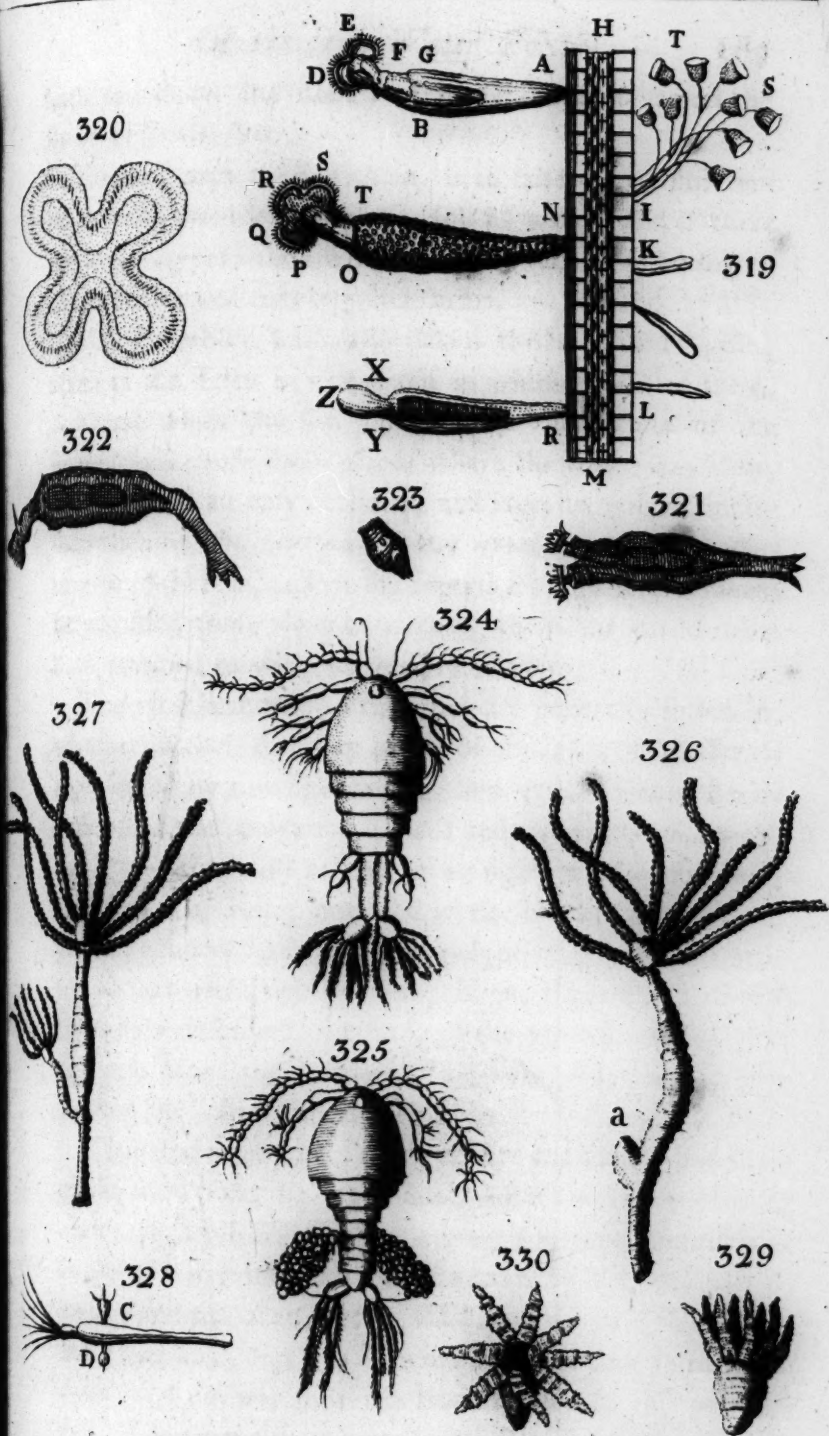
He only looked upon the motion of these two parts, as signs of the weak remains of life, especially with respect to the hinder part, and therefore observed it only to know how long it would remain alive, not in the least hoping to be the spectator of this so marvellous a reproduction.

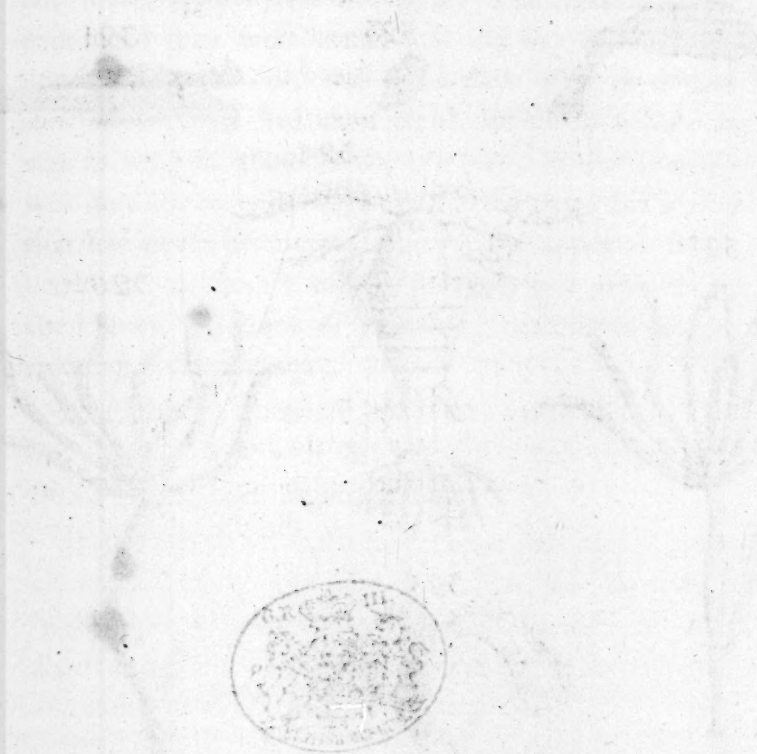
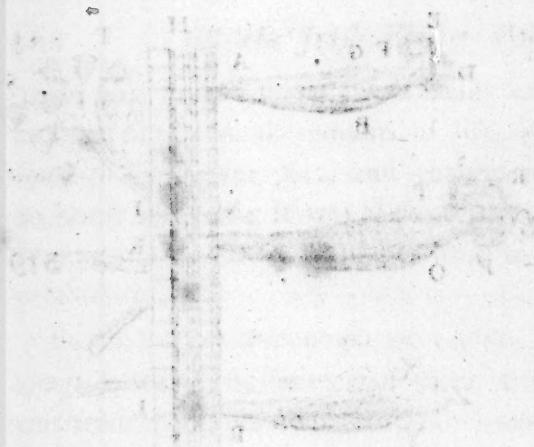
But observing the cut pieces on the ninth day with a magnifying glass, perceived three little points coming out from the edges of the anterior end of the second part, which had neither head nor arms. The next day he was convinced they were arms, and the day following two new arms came out, and some days after three more; this second part had then eight, which in a little time was as long as those of the first part, so that now there was no difference between the second part, and a polype that had never been cut. They both appeared sensible, being each of them complete polypes, and performing all the known functions of stretching themselves out, contracting and walking.

After this he discovered one in a great glass he had by him, which was well stored with green polypes, from which young ones began to shoot.

In the month of April he found a new sort of polypes, represented at fig. 332. and soon after saw them eat and swallow down worms longer than themselves, and to digest them and be nourished therewith: therefore this is a certain proof of their being animals.

They are to be found indifferently upon all sorts of aquatic plants, and other bodies that are in the water (upon which they fix themselves by the tail) at the bottom of ditches, and are suspended upon the surface of the water, upon branches of trees, boards, rotten leaves, bits of straw, stones, and many of them Mr. Trembley hath





hath found on the bodies of divers animals, as on the shells of snails, &c.

The best way to find them, is to take up the different bodies and put them in glasses full of water, and if there are any polypes, they will soon be perceived adhering to those bodies and moving their arms.

Mr. Trembley hath also taken the trouble of going often to the sides of the ditch in which he found them, at a time when the sun shone upon the bottom of the water, and chose those places where the water was clear, and that had an easy declivity, and says, he hath distinctly seen them at the bottom of the water, on all the bodies that were therein, and on its superficies; by which means he acquired those ideas concerning them, he could never have attained to without this precaution.

The most common posture they are generally found in, whether in their ordinary places of abode, or in glasses, is represented by the figures 331. and 332. The posterior end *b*, of the polype *a b*, is fixed against a plant *e f*, fig. 331. or against a straw *g h*, fig. 332. the body *a b*, and arms *a c*, being extended in the water.

The general figure of the polype's body in this attitude is not perfectly the same; in the three kinds of polypes here described, the body of the green ones, fig. 331. diminish from their anterior to their posterior end, the diminution being almost insensible.

That sort represented fig. 332. are the same; but those of the third sort, fig. 333. differ from the two preceding ones in this respect, that their body does not diminish insensibly, but from the anterior extremity *a*, to the part *d*, and sometimes even to two thirds of the length of their body; as at *d*, fig. 334. becoming from this point much finer, and do not diminish from thence to the posterior end. They wave their arms in all directions, as at *a*, *i*, *k*,
fig.

fig. 331. at a and e, fig. 332. and at a, fig. 333. and 334. The number of their horns in these three sorts of polypes, is generally at least six, and at most twelve or thirteen, yet nevertheless there are some few of the second sort which have eighteen arms. They can contract their bodies till they are not above the tenth of an inch or thereabouts in length: for example, that represented at fig. 333. could contract itself so as to become like those two representations fig. 335. They can also stop at any degree either of extension or contraction, from the greatest to the least.

The green ones are generally about half an inch in length when stretched out. Those of the second and third sort are most commonly between three quarters of an inch and an inch; but some may be found of both sorts, whose bodies are an inch and half long.

They grow smaller as they extend, and increase in bulk as they contract themselves. The figures 331. 332. and 333. represent the general and natural size of these three sorts of polypes; and at fig. 362. is an exact representation of one, as it appears in the microscope.

You may oblige them to contract more or less, in proportion as they are touched, or as the water in which they are, is agitated more or less. Every polype, when taken out of the water, contracts itself in such sort, as to appear like a mere lump of jelly on the body it is fastened to, as at fig. 336. which figure is so different from what it bears when stretched out, that it can scarce be known at first sight, but when the eye is once accustomed to it, they are easily distinguished from all other bodies that are out of the water.

Heat and cold hath the same effects on the polypes, as it hath upon all other land and water insects. Heat animates, and cold benumbs, or makes them faint and languid;

languid; yet nevertheless it requires a considerable degree of cold, to reduce them to a motionless state, and that must be very near to that of freezing, at which time they are more or less contracted, and so remain; but as soon as the water in which they are, acquires some degree of warmth, they stretch themselves out, and move proportionably to the heat thereof. It is not necessary that this degree of heat be very considerable, but is sufficient for them, if the water be of a temperate heat, which is exactly shewn by the fifty-second degree on Fahrenheit's thermometer ^m.

The arms of the green polypes seldom exceed the length of their bodies, as at fig. 331. An inch is commonly the length of the arms of the second sort, as at fig. 332. though some are longer. The arms of the third sort are generally about eight inches, fig. 333. for which reason Mr. Trembley calls them long armed polypes.

The polype can extend and contract its arms, without extending or contracting its body; and its body, without any alteration in the arms; it can also extend and contract all or some of its arms, independant of the others.

Its body and arms are also capable of bending in all possible directions, some of which are represented by fig. 337. in which attitude they are sometimes found; the body and arms can also twist themselves, as at fig. 338. and 334. It is likewise remarkable, that the arms of the second and third sorts of polypes, generally bend at some distance from their joining to the body.

The

^m Fahrenheit's Thermometers, as well as those of Sir Isaac Newton, Mr. Reaumeur, D'Lisle, and others may be had at my shop, made after the best manner, and graduated from actual experiments; at Tycho Brahe's head, No. 60. in Fleet-street, London.

The third sort, for the most part, let their arms hang down, making different turns and returns, as at fig. 338. and sometimes they direct some of them towards the top of the water.

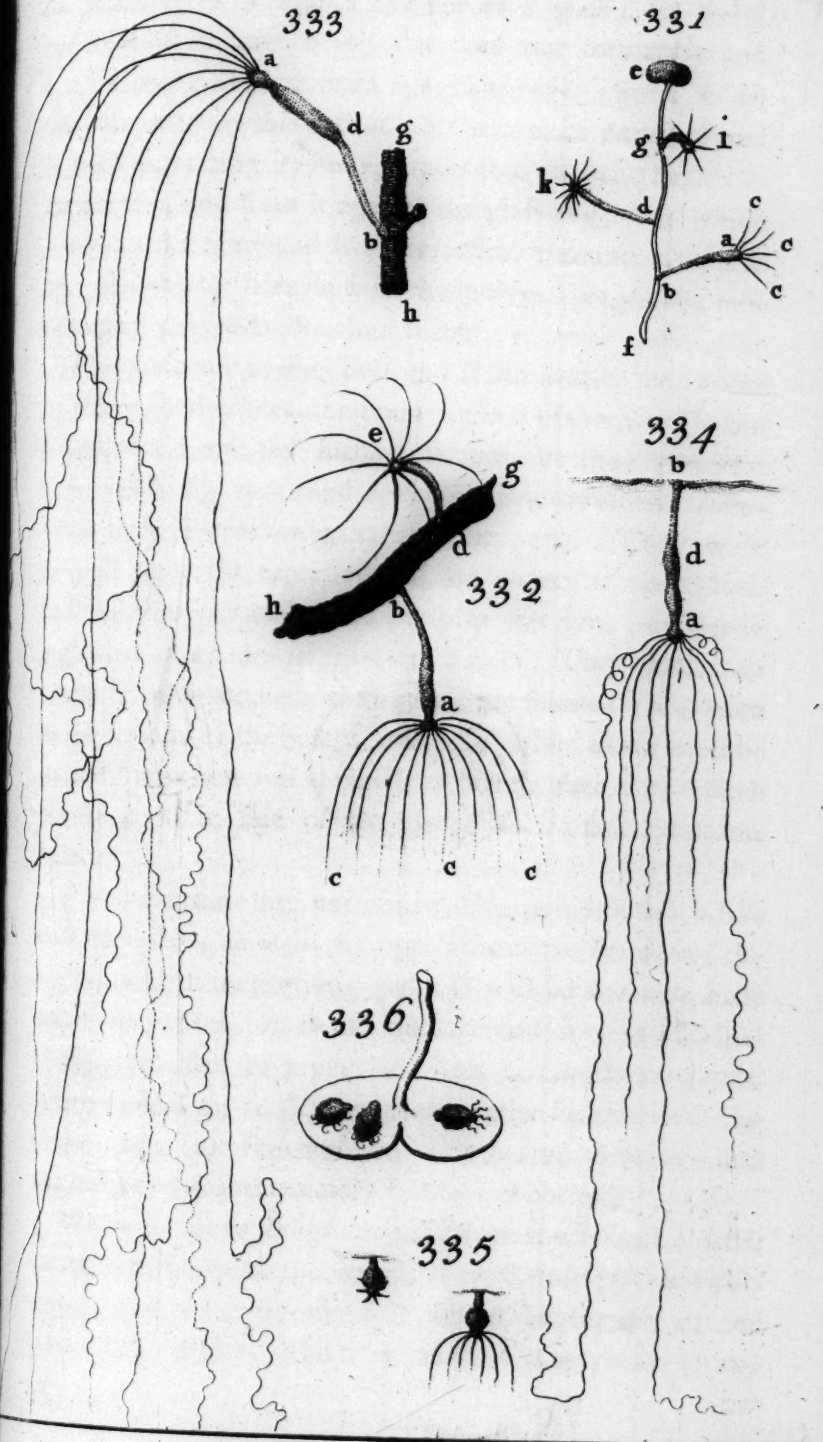
Their progressive motion is performed by means of that faculty they have of stretching out, contracting, and turning themselves every way. For let the polype a b, fig. 349. be fixed by its posterior end b, having its body a b, and arms extended in the water, in order to advance, it draws itself together, by bending its body on whatever it moves; and then fixing its anterior end a upon this body, sometimes the anterior end only, at other times some of its arms, and at others the arms and anterior end a, as at fig. 350. When the anterior end is well fixed, it loosens the posterior end b, and draws it to the anterior a, fastening the end b, as at fig. 351. after which it again loosens its anterior end a, and stretches it out, as at fig. 352. Thus much for a general description of the common steps a polype makes in moving from place to place.

They walk very slow, and often stop in the middle of a step, disposing of, and winding their body and arms every way; as at fig. 338.

Sometimes they make an extraordinary step, as follows; let the polype a b, fig. 353. be fixed by its posterior end b, and its body and arms extended in the water. First it bends its anterior end a, towards the body upon which it moves, and fixes it at a, fig. 354. after which it loosens its posterior end b, and raises it up perpendicularly, as at fig. 355, then bending its body to the other side, fixes the posterior end b, as at fig. 356. and loosening the anterior end a, raises it up again, as at fig. 357.

The third kind of step the polype makes, is in the following manner; let the polype a b, fig. 358. be fixed by

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its posterior end *b* against the side of a glass; its body, and most of its arms being stretched out forwards, and one of its arms *a c*, fixed against the glass at *c*: when the polype is in this attitude, it loosens its posterior end *b*, and contracting its body, draws it up a little nearer to the point *c*, and fixes it against the glass at *d*, after which it repeats the same and fixes its posterior end at *e*, and so on. All that is here said of the polypes progressive motion equally respects the three sorts.

They descend to the bottom of the water, and come up either by the sides, or upon aquatic plants, and often hang down from the surface thereof, by their posterior end, as at *b*, fig. 334. and are often seen to suspend themselves by one arm only, as at *c*, fig. 339. They walk as well upon the superficies of the water, as upon those bodies just mentioned; and perform the same motions in a glass, as they do in greater waters: They pass over plants or other bodies; they go up the sides of glass, even to the surface of the water, and pass either under or over it, and sometimes rest themselves there; then they march to the opposite side of the glass, and so descend to the bottom.

If you examine the extremity of a polype's tail, while it is suspended, as at *b*, fig. 334. (from the surface of the water) with a magnifying glass, it will be found a little out of the water, somewhat concave and dry, as at *b* and *c*, fig. 359. and to prove that this circumstance is absolutely necessary to support them on the superficies of the water, only wet the dry end with a drop of water, and the polype will immediately fall to the bottom.

When a polype designs to pass from the sides of a glass, to the superficies of the water, it need only put that part out of the water by which it would be supported, and give it time to dry, which is what it always does, and
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what may easily be observed. If, for example, a polype is fixed against the sides of a glass, near the superficies of the water, (on which it intends to go) as at e f, fig. 359. in order to convey itself thither, it raises up its anterior end, and puts it out of the water, there letting it dry, then loosening its posterior end f, from the glass, draws it up, and puts it above the water, where it also becomes dry in an instant, and capable to support the polype, upon which it draws its anterior end under water, and remains suspended from its surface, as at c and b, often extending its body and arms.

It has been often found necessary, in the course of these experiments, to suspend a polype from the surface of the water, because they are not always to be found suspended there of themselves. To effect which, take in one hand an hair-pencil, and in the other a pointed quill, or a tooth-pick; with the pencil loosen the polype from the glass, and gradually raise it near the top of the water, in such a manner, that the anterior end of the polype be next the point of the pencil; then lift it out of the water, and keep it so for a moment, nay a minute if you will, after which thrust the point of the pencil, together with the anterior end of the polype, by little and little under the water, until no more than about half the tenth of an inch of the polype's tail remains above its surface; at this instant, with the pointed quill, remove that part of the polype from the pencil, which is already in the water, and at the same time blowing against the polype, its tail will be also loosened, and remain out of the water.

A polype, that is already suspended, may be removed from a glass of dirty water, to a clean one with fresh water, by endeavouring to place the pencil parallel to the polype, and in this position to advance it gradually till it touches him, he will then apply himself against the pencil, and

and on being drawn out of the water, its tail, which was dry before, will remain so; and it may be immediately put into the clean water, by observing the foregoing directions.

Polypes commonly fix their tail to stones, or aquatic plants, &c. so fast as to prevent their being drove away by the stream, and are sometimes fixed not only by their tails, but by two or three of their arms also, which they direct different ways; and being thus fixed cannot be tossed about by the motion of the water.

Two long armed polypes suspended from the surface of the water in a glass, are represented exactly in the position they were found, at a, b, and c, d, fig. 359. One of them d c, had two of its arms d, i, and d, k, fixed against the bottom of the glass, but on opposite sides thereof, at i and k. The other a b had also one arm a g, fixed against the bottom of the glass, at g, and its other arm a h, fixed against the side at h; they held themselves so fast in this position, that the glass was forcibly shaken before they quitted their hold.

The polype's mouth is situated at the anterior end of its body, in the middle between the shooting forth of the arms. It is very often stretched out, at which time it represents a little conical nipple, as at a, fig. 333. and fig. 343. The cone it forms appears sometimes truncated, as at a, fig. 362. At other times no nipple can be discovered, the interval between the arms being closed, as at a, fig. 338. and 344. in other circumstances it is hollow, being open, and a little widened, as at i, fig. 331. or at e, fig. 332. and a, fig. 362. it is not only open in this circumstance, for if it is observed with a magnifying glass, when flat, or when it forms a truncated cone, a little hole is generally seen at the end thereof, which is represented as it appears when magnified at a, fig. 362.

The

The different opening of the mouth and lips, are seen fig. 343. 344. and 345.

The polype's mouth opens into its stomach, forming a kind of bag or gut, from head to tail. The naked eye may be convinced of this, but much better if it be armed with a microscope. It is exactly represented as it appears through the microscope at a b, fig. 262.

Mr. Trembley not being satisfied that the polype was perforated from end to end, by only observing it from without, cut one transversely into three parts, each piece immediately contracted itself, and remained very short, and being all three placed on the flat bottom of a shallow glass full of water, and viewed through a microscope, from the upper end, the bottom of the glass was seen through the lower, so that all the three were visibly perforated; they are represented as they appeared in the microscope, by the figures 340. 341. and 342. Its mouth was at the anterior end of one of these parts a, fig. 340. and was then wide open. The posterior extremity was at the end b of the third part, fig. 342. as this piece was perforated through, it plainly appears, that the tails of the polypes are also open.

This perforation which is continued from one end to the other of the polype, is called the stomach, because it contains and digests the aliments, and the skin which incloses the stomach, and forms this bag, is the very skin of the polype. Therefore the whole animal consists but of one skin, disposed in the form of a tube or gut, open at both ends.

If a polype be observed with the microscope, its whole body appears like shagreen, or as if it were strewed with little grains, as represented at fig. 362. both when contracted or extended, it is more or less varied according to these or other circumstances.

If the lips of a polype be cut transversly and placed upon the object-carrying glass, in such a manner as that the cut part of the skin a, fig. 341. may lie directly before the microscope, it will be found to consist of an infinite number of those little grains throughout the whole thickness of the skin: therefore, in order to know whether the inside of the stomach had any of the like grains, Mr. Trembley opened several of them in the following manner; by putting a polype upon his hand, he made it, by touching, to contract as much as possible, and then he introduced a very fine point of a pair of scissars into its mouth, and forcing it out at the tail, and immediately closed the scissars, which cut one side of the polype's skin from the top to the bottom, and laying it open from one end to the other discovered the interior superficies thereof, which is represented as it appeared in the microscope at fig. 346. and this was also composed of as great a quantity of the same grains as the exterior superficies and the edge a, of the cut piece of skin, fig. 346. To examine these particulars a little farther, a bit of the skin was laid upon a glass slider in a drop of water, and placed before the microscope, a, fig. 347. and some of these grains separated therefrom, as at b, c, d, by pressing them with the point of a pin, striking them against the glass, and endeavouring to tear them in pieces; the grains spread themselves to all parts of the water, and at last remained in heaps as at e and f.

If a polype be carefully placed before the microscope, so as not to wound him, you will seldom be disappointed of seeing those grains separate from some part or other, and that in the most healthy polypes; but when they separate in large quantities, it is a certain symptom of a dangerous illness. The surface of the polype from which they fall becomes irregular, and is no more terminated as

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before.

before. The grains fall off from all sides, it contracts itself, the body and arms swell and lose their shining whiteness, and at last their form, as at a, fig. 348. and nothing is to be found in its place but an heap of grains as at b.

The structure of the polype's arms bears a near resemblance to that of its body; and when observed with the microscope, we find their exterior surface to appear shagreened also, fig. 362. an arm much contracted appears extremely so, and even much more so than the polype's body.

If a suspended arm that extends itself be observed, the grains may be seen a little asunder, which when contracted almost touch, but so that intervals are left between them, as at fig. 363. When at a certain degree of extension, its surface seems only to be strewed with pimples as at fig. 364. which continue still to separate, as the arms extend, and are at last placed upon a thread e e e, fig. 365. These pimples are formed by the reunion of many grains, and at the first glance appear like a string of beads, fig. 365.

The different states of a polype's arm, may be observed at the same time, in the same arm, but at different places thereof, by casting the eye, armed with a microscope, from one end of the arm to the other, and especially if the several portions thereof be carefully observed with a large magnifier, they will appear as at fig. 363. which represents that part of the arm stretched out, which is near the polype's head, the grains thereof being but little separated, but are farther asunder in fig. 364. which is about the middle of the arm; and fig. 365. shews the grains as if they were strung upon a thread, as they are seen upon the extremity of a polype's arm.

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348

b



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340

b



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d

b

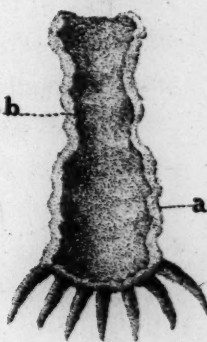
a

c

e

f

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344

343





This extremity is often terminated by a knob, and the hairs marked e, e, e, fig. 364. 365. are transparent, and may be seen with the first and second magnifiers.

The best method to observe a polype's arm, is to choose one that is fixed to the side of a glass, and near the superficies of the water: at which moment, any one of its arms being very well extended, take a pair of nippers in one hand, and a slip of glass, about two or three inches long, and half an inch broad, in the other, holding it at one end between the finger and thumb; then with the nippers, or a pointed quill, pull the end of the arm gently out of the water, and the rest will follow. If it is not stretched enough, stretch it more, by drawing it out, the polype still remaining fixed to the glass; put the arm upon the slip of glass, and turn it under till it meets itself again; then giving it a jirk, the arm will break off on both sides the slip of glass, one part remaining with the polype, and the other in the forceps, and the middle part will stick upon the glass slip, in which manner it may be applied to the microscope, and preserved for several days, as well as when it is at first taken out of the water, for when once dry it does not change for a considerable time.

Of the polypes food, and manner of their
seizing upon, and swallowing their prey.

IT was some time after the discovery of the second sort of polypes, before Mr. Trembley could find out a proper food to nourish them, but the water at that time happened to be plentifully stored with a sort of millepedes, fig. 360. small enough, and about three quarters of an inch in length. They are remarkable

for a horn, or fleshy dart, proceeding from the fore part of their head at d. Mr. Reaumeur had called them darted millepedes. They support themselves, and swim in the water by means of the several swift inflections they make with their bodies; they rest themselves, and creep upon all the bodies they meet with, and are often found in great numbers upon aquatic plants; those upon which the first polypes of the second sort were found, were well stocked with these millepedes, and were taken out of the water together with them, and put into the same glass without any design.

A few days after the anterior end a, of a polype, fig. 366. was observed, with one of these millepedes partly within its mouth, and the other part yet without it at m, not knowing at first whether the polype was eating the millepedes, or whether the millepedes had introduced itself voluntarily into the polype's stomach, to be nourished there, to lodge its eggs, or deposite its young therein, but at last it was entirely entered into the polype's body.

The long armed polypes being the most remarkable in their feeding, &c. for that reason principally, Mr. Trembley thought proper to describe these experiments, upon that sort, from which one may easily judge the same of the other two sorts.

To see these polypes seize their prey with their arms extended, they must be put into a glass, seven or eight inches deep, if the polypes are fixed to the top of the glass, their arms for the most part hang down towards the bottom. This is then the most convenient situation to give them food, and to observe how they manage it. To this end one might cause them to hang from the surface of the water, but this expedient is not always best.

The polypes we breed and feed, are commonly infested with little lice, it is therefore necessary to cleanse them from these tormentors, by rubbing them with an hair pencil, and if the polypes suspend themselves from the surface of the water, it is scarce possible for them to be freed from these lice. In that case make the polypes fix themselves to a packthread, or fix them to it, as at fig. 367. at the place b, letting the two ends h f, and k g hang down over the edges of the glass. One may then stroke them even something rudely, backwards and forwards, with an hair pencil, without pulling them off, and in changing the water, only take hold of each end of the pack-thread, draw it gently out of the water, and put it immediately into another glass, prepared for its reception. If several of these pack-thread strings are put into a glass well stored with polypes, there will be always some that will fix ^a themselves thereto.

When the arms of the polype are well extended, put a millipedes, or any other worm into the glass, and with the point of a pencil, push it to one of the arms, which it no sooner touches, but it is seized, and when the millipedes m, c, n, or worm, perceives itself taken, it endeavours by very quick and strong efforts to disengage itself, often swimming and dragging the arm a c, fig. 367. from one side of the glass to the other; this violent motion of the millipedes, obliges the polype to contract its arms, in the performance of which he often disposes them in the form of a corkscrew, o i, which also contributes to the shortening of it. The millipedes by its continual struggles, entangles itself in the arm that holds it, m i n, and often meeting with other arms, they also assist, and with a sudden pull, enable the polype to con-

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tract

tract himself, or to draw near his prey, and in an instant the entangled millipedes is conveyed to the mouth, against which it is held and subdued.

When a polype hath nothing to eat, its mouth is generally open, but that so small that it cannot be seen without the assistance of a magnifying glass: whereas, as soon as the arms have conveyed a prey to the mouth, it opens itself more, and always in proportion to the size of the animal that is to be devoured; its lips gradually dilate, and precisely adjust themselves to the figure of their prey.

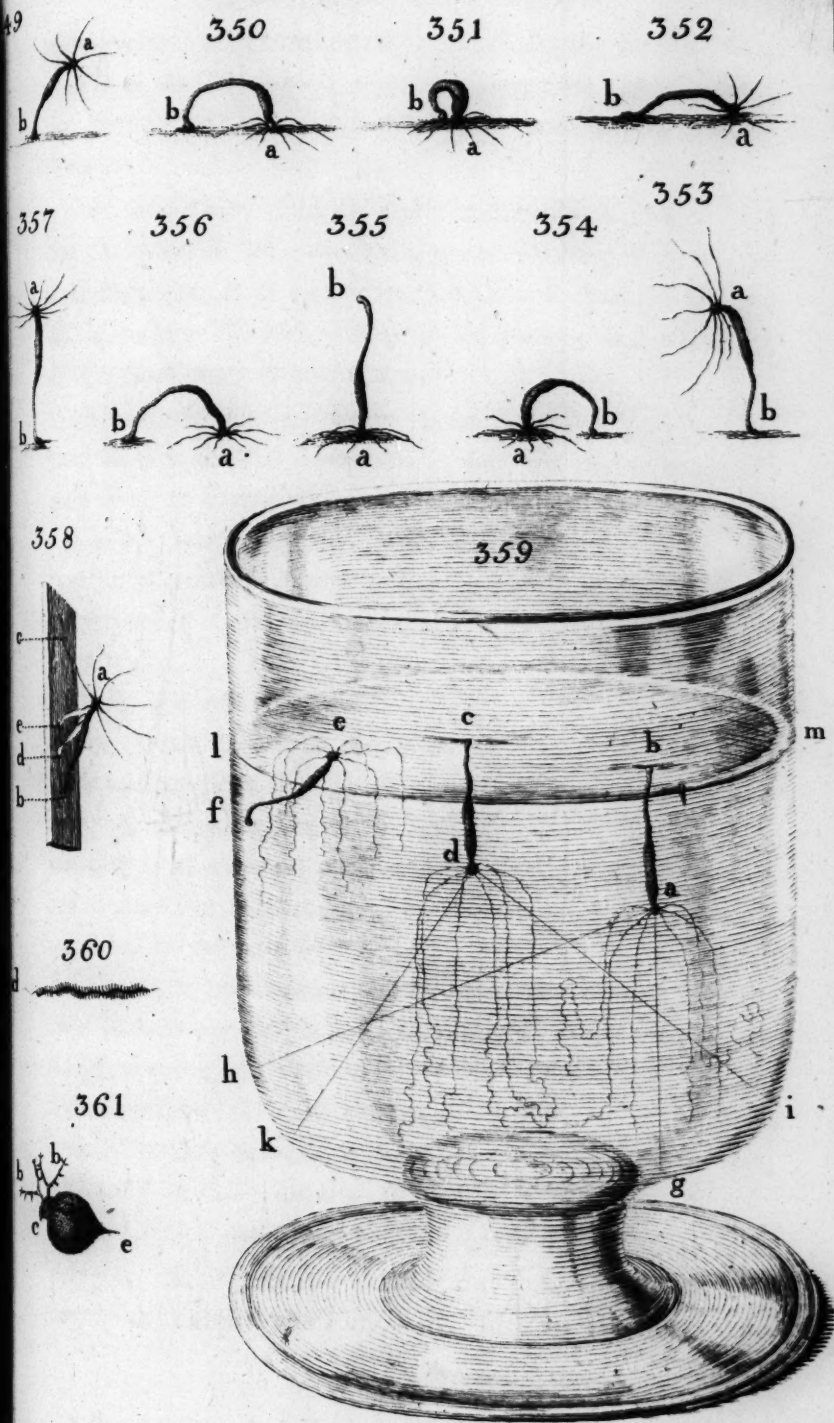
All the worms which are seized by the polypes, do not present themselves in the same manner to their mouth; for if the worm presents itself by one of its extremities, it is not requisite the polype should open its mouth considerably, neither does it open otherwise, but precisely to give entrance to the worm, fig. 366.

If the worm is not too long for the stomach, it remains therein extended; but if longer, that end which first entered bends, and when it is entirely swallowed it may be seen folded within the polype, fig. 379.

When the middle or any other part of the worm is presented to the polype's mouth, it seizes this part with its lips, extending them on both sides, and applying them against the worm; at which time its mouth takes the form of a boat pointed at each end, fig. 368. after which the polype gradually closes the two points of its boat-like lips, which doubles the worm in that part, and so it is swallowed, fig. 369.

As soon as the stomach is filled, its capacity and the skin thereof is augmented, and the body becomes short, fig. 372. its arms also are for the most part contracted. The polype hangs down without motion, and appears to be in a state of numbness, and in shape very different

from





from that of its extension, fig. 367. As the food digests, and it voids that which does not serve for nourishment, its body lengthens, and gradually recovers its natural form.

Mr. Trembley finding these millepedes a proper food for the polypes, he collected a great quantity of them, to feed those he kept in glasses, and found them in swarms at the sides of ditches, creeping on plants, and all other bodies that were in the water.

Also on observing how voraciously the polypes eat these millipedes, he imagined it was not the only agreeable food to them, and was therefore desirous of finding out other animals to nourish them withal, besides the trouble of getting a sufficient quantity of millipedes from other places took up too much time; upon which he opened a polype that was taken out of the water, with its belly full of food; from whence came out little insects, which he calls pucerons or fleas, and amongst these another sort that multiply extremely, and are often easily to be procured in great quantities; see the fig. marked p, at the end of one of the arms, fig. 367. which represents one of these fleas of its natural size, and as it appeared in the microscope at fig. 361. They are exactly described by Swammerdam^o, and are remarkable for two branching arms, which proceed from their head, which serve them instead of fins. The arms inclined Swammerdam to call them by the name of puceron branchus; they are continually skipping about the water, and are generally somewhat reddish.

On putting some of these pucerons into a glass with polypes, they presently seized on some of them, and began to extend their mouths, first in the form of a

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concave,

^o Swammerdam's Hist. de Insect. p. 86. Edit. de Leid. 1737.

concave, in which part of the flea is lodged, as at a, fig. 370. the lips continue to enlarge, till they included the puceron, and then entirely close themselves again.

The polypes are not content with two or three of these pucerons, but will continue to swallow them till the sides of their stomach are so increased, as to contain two of these fleas in breadth one by the side of the other, as at fig. 371. which was absolutely full from head to tail. If it be one of the third sort, the narrow part of its body b d, fig. 372. generally remains empty, but sometimes this also is forced to increase and receive some of those fleas. When the polype hath swallowed no more of these fleas than can be contained within its stomach; its body, in that case, becomes very small near the head, and forms in that place a kind of remarkable neck c, fig. 373.

If a number of these little fleas be hastily thrown into a glass of hungry polypes, their arms are soon so loaded with them, that one can see nothing but a confused mass of these pucerons gathered together, near the polype's mouth a, fig. 375. which they swallow one after another till they are entirely full.

So long as these pucerons could be procured, he fed his polypes with nothing else: his method of fishing them out of the water, was with a small hoop, of about eight or ten inches diameter, made of brass, or iron wire, to which was fastened a pouch of linen cloth, and the whole tied to the end of a stick. This being put slope-wise into the water, where there is a quantity of these animals, may be easily moved to and fro, any way you see occasion, by which means the fleas will be gathered together into the hoop. You may then put them into a glass of water, which will swarm therewith from the beginning of June to the end of September; these were

easily

easily to be procured, but when they began to fail, he was at a loss to find out other nourishment for his polypes.

He went several times a day to the water-side, which had before a long time furnished him with fleas, and stooped down near the surface of the water, endeavouring to discover young ones, but all in vain; nevertheless in seeking these he saw several places at the bottom of the water, with worms all standing an end, one end of which was in the earth, and the other end out of the earth in the water, making continual undulations, fig. 376. He thought, as soon as he saw these worms, they would serve to nourish the polypes, and to make up for the fleas he wanted, and the millepedes which could at that time be found only in small quantities; it was with a great deal of trouble that he took up some of those worms, which he gave to the polypes who eat them. Therefore, to procure as many of these worms as you may have occasion for, you need only fix a circle of iron wire, two or three inches diameter, to the end of a stick, and putting this into the water, and about half of it under the earth, run it along a little way, always holding it in the same position, and that a little inclined; this will meet the worms, and drag them along with it, and bring up a large quantity thereof, which on shaking the wire circle in a glass of water, will all fall to the bottom. If the ditches where you fish for these worms should be covered with leaves and herbs, it is necessary first to cleanse them with a rake, before you put in the iron circle, otherwise you will get but few worms at a time. There are also other places so muddy, as to hinder the wire from holding the worms; in this case it is expedient, that you throw upon the mud some inches of sand, for as the worms are obliged to keep part of their bodies above the

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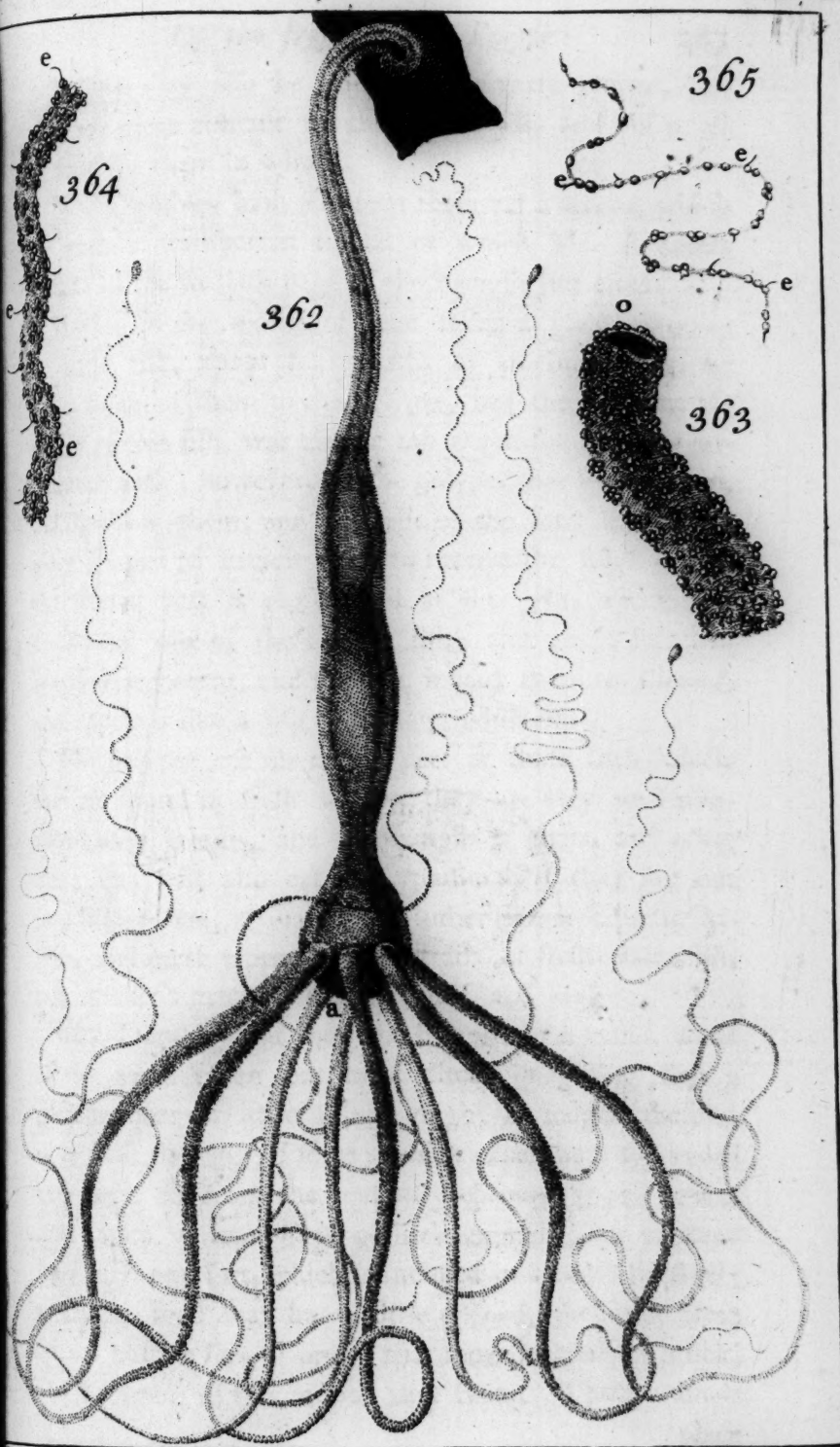
the superficies of the earth, they quit the dirt, and pass into the sand, and remain near the superficies thereof. They may be taken in very great quantities, after preparing the bottom of the water in this manner.

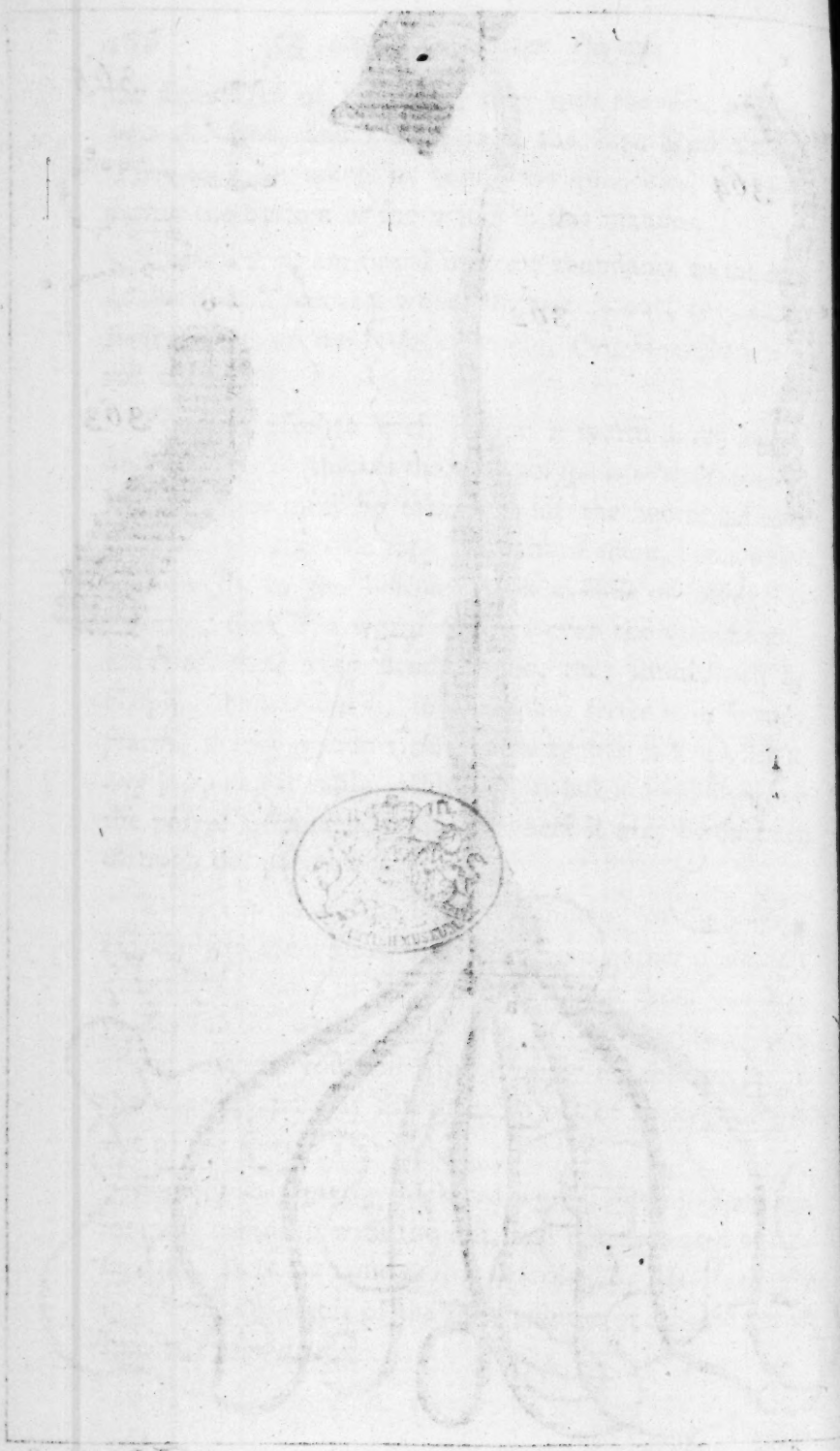
These worms are found in great abundance in the mud of the river Thames; when the tide is out, they rise in such swarms on the surface thereof, that it appears of a red colour.

You may give to each polype a worm much longer, and also a little thicker than the polype is when extended; but then care must be taken to let the worm fall upon their arms, otherwise they will miss of them, because they fall directly to the bottom. Their sense of feeling is so delicate, that if a worm touches even the utmost extremity of these very slender arms, they immediately by clasping them about it, envelope and fetter it in so many places, that it is soon rendered incapable of struggling to any purpose, it easily yields, and at last is swallowed into the polype's stomach, fig. 380. where it may be discerned through the polype's skin.

These worms are the best nourishment for the polypes, especially in the winter, therefore if you gather a sufficient quantity of them in November, and put them into large glasses full of water, with three or four inches of earth at the bottom, you will have a supply for the polypes all the winter, and may fish them up out of these glasses, as out of the river.

Sometimes a pretty thick red worm, about half an inch long, is taken up with the rest, and is represented at c d, fig. 382. It is the same as that described by Mr. Reaumer, in the first Memoir of the fifth volume of his *History of Insects*, page 29.





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Polypes may also be nourished by these worms, but they are more difficult for them to digest, and not at all fit food for them in winter.

Mr. Trembley hath also seen them eat a worm, which he calls a transparent tipula, of which Mr. Reaumer speaks in the fortieth page of the memoir just cited.

Having in the month of June taken a great quantity of little fish, about four tenths of an inch long, he gave some of them to the polypes, but the extreme vivacity of this fish, was almost too much for them to encounter with; however, all the polypes that seized them, did swallow them, and the tails of the long armed sort were obliged to stretch open to receive the fish: one of the second sort is represented at fig. 377. which had swallowed one of these little fish; and as its skin a b, was so transparent, and flexible, it took the form thereof, and appear'd like a fish with long whiskers.

The polypes eat the major part of those little insects that are found in fresh water; they are very well nourished with worms, and the nymphs of gnats, and other flies; they will also eat larger animals if they are cut into little pieces, as snails, and other larger aquatic insects, and earth worms, the entrails of fresh-water fish, and butcher's meat, as mutton, beef, and veal.

Mr. Trembley put into the bottom of a vessel, some of the earth taken out of a ditch, imagining that a great number of little insects might be lodged therein, or at least the eggs of some; which experiment succeeded very well, for from the end of February 1742. it was stored with various sorts of little animals; but particularly with one sort, which is inclosed in a two-fold shell; when this shell was but a little opened, they put forth several minute feet or arms, that move exceeding quick, and by means of this motion they swim. These animals
place

place themselves upon all bodies they meet with, and are about the bigness of a grain of sand; some polypes being put into this vessel, without taking any other care of them, were nourished therein, and multiplied for eight months.

Whence it appears, that large glasses or pails, thus prepared with earth, (at the bottom of them) taken out of ditches in the summer-time, will be a convenient residence for the polypes; for besides those insect eggs that are contain'd in this earth, may be very often seen (especially if the water in the glass be exposed to the air) the spawn and nymphs of gnats, and of *tupula*, or water-spiders, &c. These vessels may then be successfully employed, and will save the trouble of feeding the polypes we intend to preserve, and also of often changing the water. But when it is not changed and cleansed for some time, it is generally filled with an herb, as fine as hairs, in which the polypes entangle themselves, and by which we are hinder'd from looking within-side, if the vessel be not made of glass; however this inconvenience is prevented by putting into each vessel a few aquatic snails, more or less in proportion to its size; they will eat these plants as fast as they grow, whereby the water, and the sides of the vessel, will always remain clean.

Sometimes two polypes seize the same worm, and each begins to swallow its own end of the worm, continuing to do so till their mouths meet, fig. 378. In this posture they remain for some time, after which the worm breaks, and each polype hath its share; but at other times the battle does not end there, for each of them continuing to dispute the prey, one of the polypes opens its mouth advantageously, and attempts to swallow the other polype with its portion of the worm, which he effects in some degree, and sometimes almost entirely as at fig. 380.

Nevertheless

Nevertheless this combat ends more happily than we can at first believe, in behalf of the devoured polype; for the other gets the prey entirely out of its stomach; and the devour'd one comes forth again sound and safe from the body of its enemy, after having been detain'd there above an hour.

Polypes can eat a great deal at a time, and they can fast a great while; and they void their excrements at their mouth.

After a worm is swallowed, the transparency of the polype's skin will permit us to see it distinctly, as at fig. 379. the worm gradually loses its form, and is at first macerated in the stomach of the polype, the juice nourishes, and being separated, the remains thereof are thrown out at the mouth, as at fig. 381.

It is also observable, that their aliments are pushed backwards and forwards, from one extremity of the stomach to the other, which contributes much to its digestion; which motion may be seen in the microscope, if you choose a polype that is not too full. This kind of peristaltic motion spreads the nourishing juice all over the stomach. But for an observation of this kind, it is best to feed the polypes with such aliments as can bestow a lively colour'd juice; for example, those worms whose intestines are full of a red matter, for by this means we may see, that this alimental moisture is conveyed not only to the extremity of the body, but also into its arms; whence it is plain, that a polype's arms are perforated, each of them forming a kind of gut, which communicates with that of the body.

This was confirmed by examining a polype, which had sucked the red matter contained in the intestines of a flat worm, fig. 383. Its body is of a transparent white, and intestines extreamly visible, and of a crimson red;

care

care must be taken to choose those which are of a proper size for the polypes to swallow; they come out of the polype's body without being macerated, the red matter which was in their intestines being only extracted from them.

But this experiment was yet better confirm'd on giving a polype some bits of the skin of a little black, flat snail, to be met with in great abundance in ditches. The matter of this skin was soon reduced in the polype's stomach to a kind of pap, principally composed of little black fragments, and on examining their motion attentively with the microscope, were seen to be drove about in their stomach, and to pass from head to tail, and into their arms, even to a thread; and afterwards were sent back into the stomach, and chased from thence to the extremity of the tail, and were again repelled from thence towards its mouth, and into the arms, and so on continually.

These experiments were several times repeated, and succeeded in the same manner.

They are also a proof of the polype's arms being tubular, and that they have an open communication with the stomach.

The arms of the polype are of the same colour with its body, and an heap of the extravasated grains before spoken of, are of the same colour also; it is therefore evident that the colour of the polype depends on the colour of those grains which compose the skin, (for when the polype becomes white, they lose those grains) and their dependance is upon the nutritive juice, drawn from the aliments.

These grains, for example, become red or black, if the polype be fed with a red or black juice; they are more or less ting'd with these different colours, in proportion

to the strength and quantity of the nutritive juice. It is also observable, that they lose their colour, if not fed with aliments of the same colour to themselves, and likewise that they will fast a great while, but then they waste proportionably to their fasting.

They are also subject to be infested with a kind of aquatic lice before spoken of, which are very common in exposed waters; they are of an oval figure, and generally white; they run very swift upon the polype's body, and crowd about its head more than any other part, as at fig. 385. Nevertheless they may be seen in great numbers running over the body a b, and arms a c c. The present figure is a representation of the polype and lice, as they appear in the microscope. If proper care is not taken to keep them clean from these animals, they will be devoured by them, their arms will gradually diminish, and at last their body, till there is nothing left. Fig. 386. represents one that had all its head part eat up, which after having been cleansed, had a new head, and new arms, and became a very fine polype.

Therefore the best way to preserve these animals in health, is often to change the water, and that especially after they have done eating, It is not enough to pour it off, but they must all be taken out, and the bottom and sides of the vessel rubbed clean from the slimy sediment adhering thereto, which is caused by the fæces they disgorge therein, which are converted into a kind of slime, fatal to them if not clear'd away, My way is to loosen their tails from the sides or bottom of the glass, then I take them up one by one with a quill, cut scoop fashion, and place them in another glass with clean water; sometimes they cling to the quill in such a manner, as not easily to be disengaged. The only way then is to let the quill remain a minute or two in the water,
till

till they discharge themselves, otherwise you'll be in danger of breaking their arms off, however when an arm is broke, it is quickly repair'd again, but for some days there appears a swelling or callosity in the place which wears off in time.

River, or any other very soft water, agrees best with them, or what is taken up clear out of some ditch or pond; but that which comes from a spring or pump, or is in its own nature hard or sharp, prevents their thriving, and kills them in a few days.

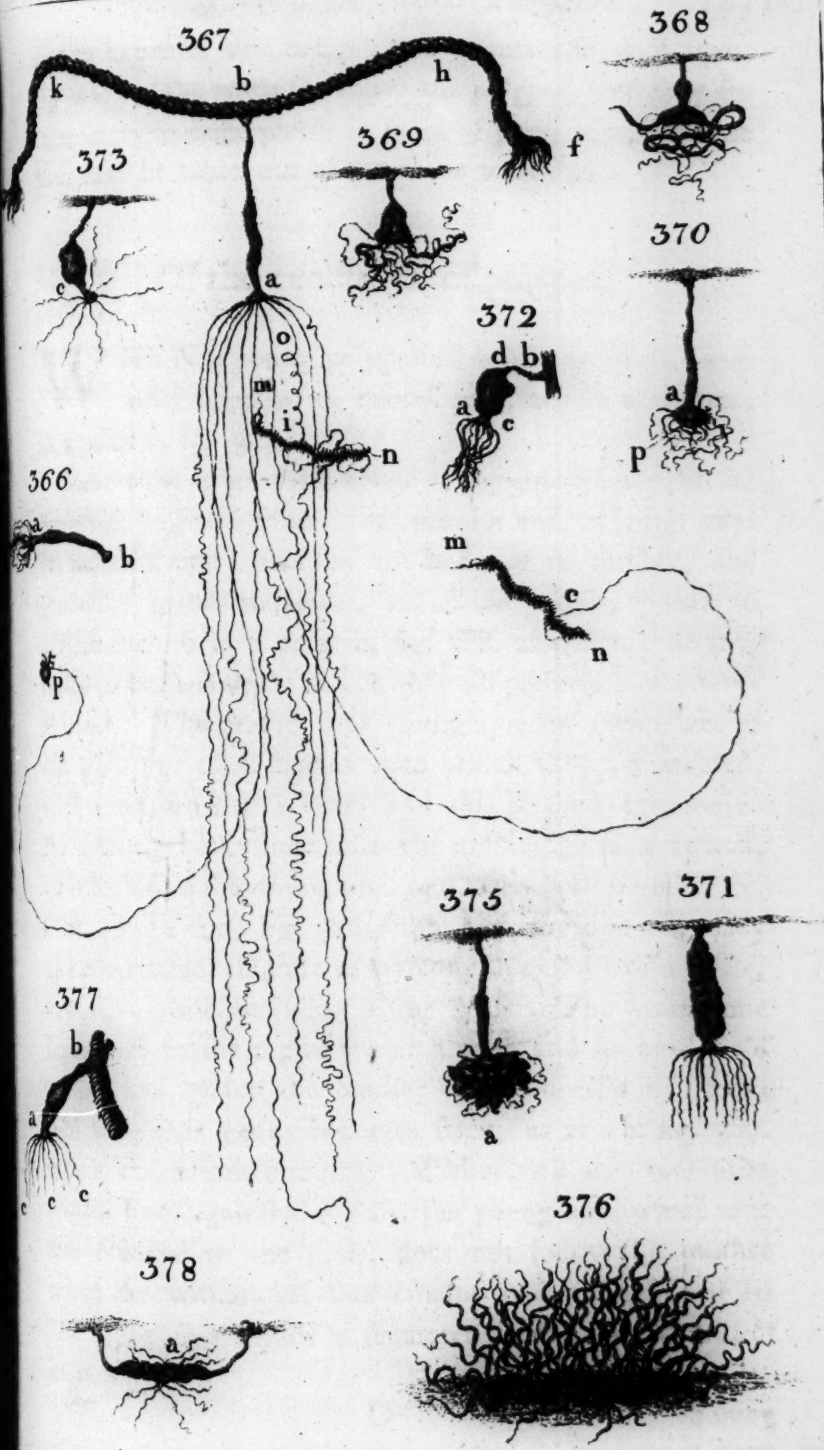
They are best kept in such large glasses as hold three or four quarts of water, for in a glass of this size, the water need not be renewed so frequently, especially if the faeces are taken out from time to time, with the feather'd end of a pen, to which it very readily adheres. Besides the trouble is in some measure saved of feeding each particular polype, for here you need only throw in a parcel of worms, and let them take their chance, but then all of them are not constantly fed, nor any of them so often as in the smaller glasses.

The worms you feed them with, must also be well cleansed from the mud, and always remember to wash them in clean water, every time you feed the polypes therewith.

Polypes are to be sought for in the bye-corners of ditches, puddles, and ponds; for it is observable, that the wind drives them together with the plants, upon which they float into these places; although we may search for them in some places without success, yet on coming there again, they may perhaps be found in great abundance.

There are fewer of them in the waters in winter, than in the other seasons. About the month of April, duckweed begins to rise above the superficies of the water

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and to increase, and many other plants also float upon the water; the warmth revives the polypes, and they fix themselves to these plants in quest of prey, at which time they may be taken out of the water with them.

Of the generation of polypes.

WHEN a young polype first begins to shoot, there only appears an excrescence, which terminates in a point e, fig. 387.

Some time after that, when it appears cylindrical, its arms also begin to shoot at its anterior end, c, i, fig. 387. Its posterior end is fixed to the body of its mother, and gradually grows narrower, till at last it only appears to adhere thereto by a point b, fig. 388. at which time it is ready to be separated; which they all perform in the same manner. The mother and young one fix themselves to the glass, or other bodies upon which they are situated, with their arms and head, and this is their preparative for a separation; sometimes the mother gives a twitch, at other times the young one, and often both together.

A polype a b, fig. 389. with a young one c d, ready to be separated, disposes of its body in an arch of a circle, a, b, d, against the sides of the glass. The young one being fast to the top of the arch at d, and its head fix'd against the glass; the mother only contracts her body, which by that means becomes strait, as at a b, fig. 390. which was before circular. While both its extremities remain fixed against the glass, the young one, which was also fastened to the glass, does not follow the mother when she withdraws, but remains in its place, and its tail d, by this means is separated from the body a b, of its mother.

O

Young

Young polypes shoot in proportion to the warmth of the weather, and quantity of food the mother eats; some have been perfectly formed in twenty-four hours, and others not till the end of fifteen days. The first shot forth in the midst of summer, and the other in a season when the water in which the polype was contained, made Farenheit's thermometer descend to forty-eight degrees.

They shoot forth from the side of their parent as a branch from the trunk of a tree; and the excrescence which is the beginning of a polype, is nothing but, a continuation of the skin of its mother, which is swelled and raised, nay even forms a tube communicating with its mother's stomach, as appears from the following experiment; for on choosing a large polype of the second sort, with a young one at its side, which being placed upon a slip of paper in a little water, the middle of the young one's body was cut, and the superior end of that part which remained to the mother was then open; next cutting the mother on both sides of the young shoot, it became a very short portion of a cylinder open at both ends, which being viewed through the superior and open end of the polype, the light was sensibly seen in the stomach of the mother; but least there might yet be a skin, which giving passage to the light, might nevertheless separate the two stomachs, the remaining cylindrical portion of the mother was cut lengthwise, and the two opposite parts to that from whence the young one came out, were opened; and on observing it with a microscope, not only the hole t, of communication, fig. 391, was distinctly seen, but one might see quite through the end o, of the remaining portion of the young one: afterwards changing the situation of these two pieces of prepared polypes, and looking through the last opening

e,

e, fig. 392. the day-light was seen through the hole of communication i. Mr. Trembley not being contented with making this experiment once, repeated it seven times, and met with the same success in five of them.

This communication between the mother and its young may be seen on feeding them; for after the mother a b, fig. 393. had eaten, the bodies of its young ones swelled, being filled with the aliments as if they themselves had been eating them at their own mouths c d e i o.

In the long armed polypes, the young ones do not shoot out from the tail part b c, but only from the part a c, fig. 396.

It is also remarkable, that polypes do not only produce several little ones at the same time, all remaining fixed to their mother, but that even some of those little ones at that very time have two or three young ones also, of which some are perfectly formed, as at fig. 396.

This figure is sufficient to shew with what promptitude the polypes increase and multiply. The whole groupe formed by this mother and her nineteen young ones, was but an inch and a quarter long, and one inch broad Dutch measure; the arms of the mother, and the little ones, for the most part were hanging down towards the bottom of the vessel, whilst the polype was suspended on the surface of the water. This mother eat about a dozen of the aquatic fleas every day, and the little ones, which were in a state to eat, devoured amongst them about twenty every day.

All the fresh water polypes, with arms in form of horns, are mothers, for each individual of this sort produce young ones.

Mr. Trembley says, he hath nourished a thousand polypes, and never found one which did not multiply,

after it had been well fed, and always observed their motions very attentively, in order to discover if nothing passed between them analogous to copulation in other animals; but could never find any thing like it.

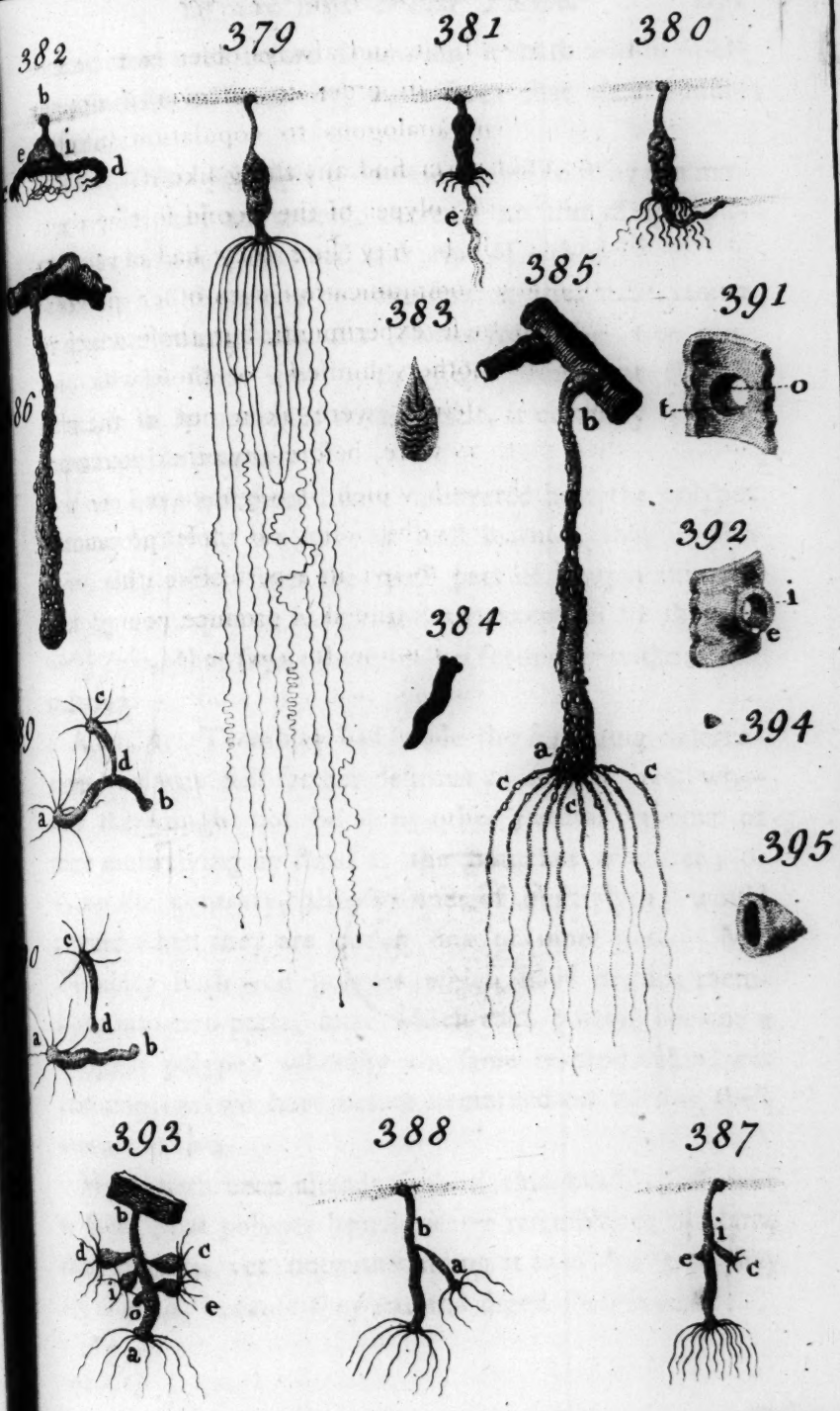
He then put several polypes of the second sort by themselves, that he might be very sure they had never since their separation any communication with other polypes; and took none for these experiments but those which he separated from the mothers himself; or those which being separated of themselves, were taken out of the glass in which their mothers were, before any other young one could be separated, with which it might have been possibly coupled; yet notwithstanding all these precautions of causing these polypes to live in a perfect solitude, they all multiplied, eat, and continued to produce young ones, more and more in proportion as they were fed.

Not only these which he first put alone have multiplied, but also many of their descendants have also been put by themselves, from generation to generation, even to the seventh, with the same precautions. Whence it appears that copulation is in no wise necessary to the production of a polype.

Mr. Trembley hath also made an experiment to prove, that a young polype had in itself the principles of fecundity, before it could be thought to receive it from its mother, or any other polype: for on cutting off a young one which only began to shoot, and at that time was only like a little button, as e, fig. 387. it is seen alone and of its natural size after it was cut off, at fig. 394. and as it appeared in the microscope at fig. 395. it was put into a glass by itself, and gradually increased, had arms, and at last multiplied.

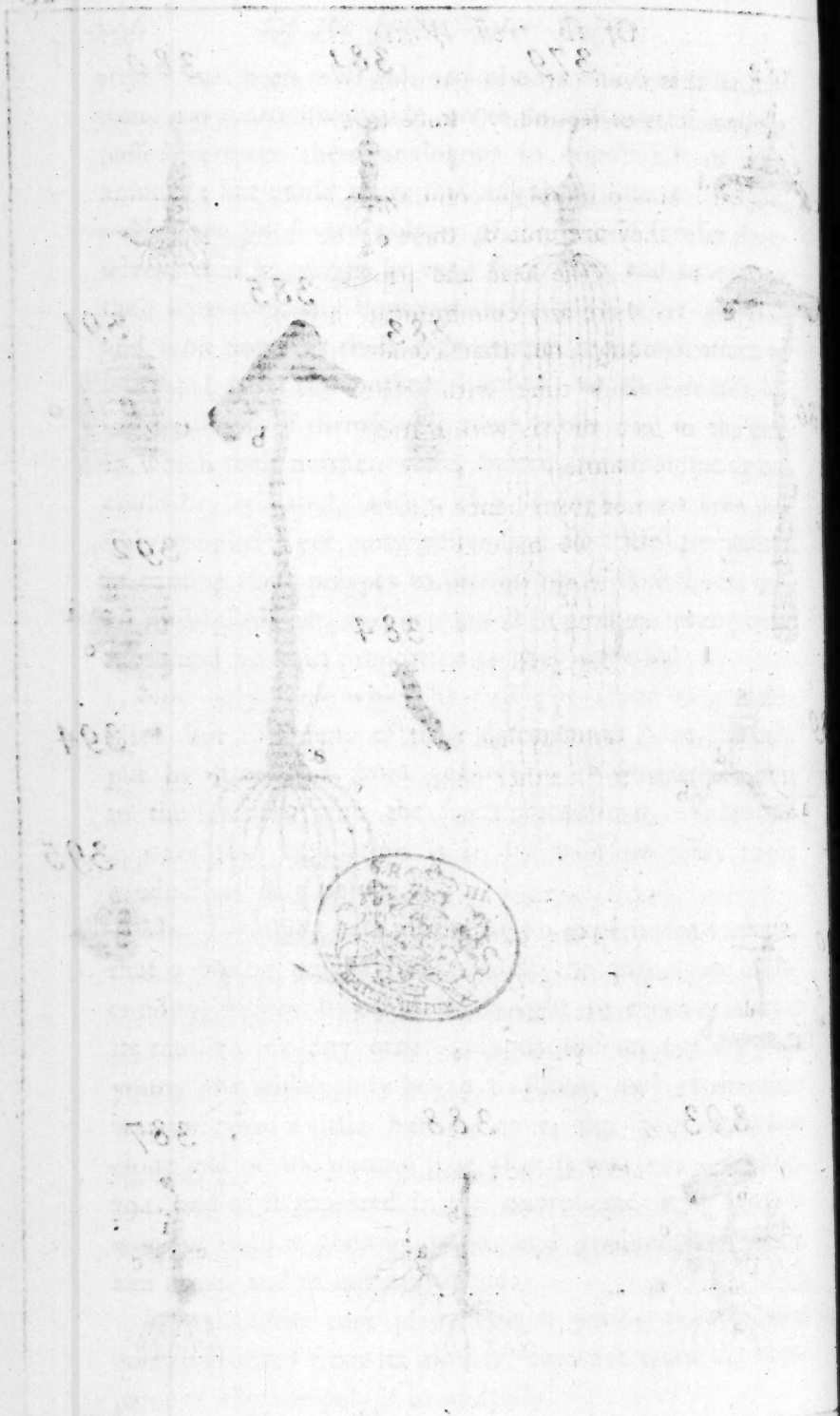
It is therefore very plain, that a young polype, after being separated from its mother, does not want the company of another polype to multiply.

And



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And that even before separation it hath within itself the principles of fecundity, since from that time it multiplies.

That if this principle is communicated to it by the mother while they are united, there is no sort of communication between the head and arms of either,

Neither is there any communication after this manner by another young one, that comes from the same mother at the same time with itself. And that if this principle of fecundity is within itself, it certainly is in an imperceptible manner.

If we have not from hence discovered how the polypes become fruitful, we have at least learned, that in this point they differ from the most part of known animals, and by consequence have made an exception to the general rule, that says, there is no fecundity without copulation.

After Mr. Trembley had made the foregoing observations, he was still farther desirous of finding out, whether there might not be some other natural manner of their multiplying by slips, as the branches of a tree; or if, on the contrary, this manner of multiplying would succeed when they are cut in one or more parts. Mr. Trembley hath seen polypes which have divided themselves into two parts, after which each portion became a compleat polype; whereby the same re-production was performed as we have before remarked on cutting these animals in two.

What hath been already said on this head is sufficient to shew, that polypes bear a nearer resemblance to plants than animals, yet notwithstanding it is evident that they are animals, because they eat and digest their food,

Of cutting polypes afunder, and their reproduction.

THE most extraordinary part in the history of this creature is this, that when cut into pieces each piece can repair itself and become a perfect animal ^p.

To perform which put a little water on a small piece of paper, whereon place a polype, and wait a little while till it extends itself; then with a pair of sharp scissars cut it into two pieces, paper and all, and examine each piece with a magnifying glass, to judge the success of the operation, putting each portion into a shallow glass which does not contain above three or four tenths of an inch in depth of water, by which means they may be always observed with a magnifying glass, or in the microscope.

A, fig. 397. represents the head part of a cut polype, its posterior end b, being a little larger than that in a common polype, and is sensibly open. In the summer-time this first part often walks, and eats the same day it is cut.

The second part, fig. 398. hath its anterior end c more than ordinary open, and the edges turned a little outwards, which afterwards folding inwards, closes the aperture: the anterior end appearing then to be simply swelled, as at c, fig. 399. This part is never seen to change its place before its re-production is finished; the arms shoot out from its anterior end as those do in young polypes, at first three or four points begins to shoot, as at c, fig. 400. and while these increase, others appear between them; before the arms have done growing they can seize a prey, and from that time its mouth is perfectly formed.

This

This re-production is performed sooner or later, as the weather is more or less warm. In the height of summer the arms will sometimes begin to shoot in twenty-four hours, and in two days have been in a state to eat, but in cold weather it will be fifteen or twenty days before the head is formed.

If a polype, having young ones, be cut transversly, the young ones continue to grow after the section.

It often happens, that the second parts which have had no young ones at the time of the section, have had young shoots before itself could eat, and before it had arms.

In whatsoever place a polype was cut, whether at the middle or near either end, the experiment equally succeeded, and each portion became a compleat polype, which walked, eat, and multiplied.

A polype being cut close under the arms, as at fig. 401. and though small as it was, it became a compleat polype, which at the beginning was all arms.

If a polype be cut transversly into three or four pieces; the posterior end of the first produces a tail, the anterior end of the last a head, and the intermediate pieces acquire both head and tail.

To cut a polype lengthwise, it must be made to contract as much as possible, because the more it is contracted the larger its body is: therefore put the polype upon a slip of white paper in a small drop of water, and when by touching it is very much contracted, drain away the water, whereby its upper and under sides collapse, and the polype becoming spread in breadth, remains fixed upon the paper; then with a sharp pair of scissars cut through both paper and polype, the divided parts will adhere to the paper like a jelly, but may be removed therefrom to the object-carrying glass, or glass slide, with

the point of an hair pencil, first dipped in water, upon which it may be applied to the microscope; or if the papers are thrown into a glass of water, the divided pieces will soon fall from them.

The sides of a polype cut longitudinally, roll themselves up different ways, generally beginning from one of their extremities, as at fig. 402. and turns the out-side of the skin inwards; after some time it unrolls, and the out-side forms itself into a tube, whereof the edges a b, and e i, fig. 403. on both sides meet each other, and reunite themselves; sometimes they begin to join at the tail end, at other times they gradually approach all at once; when they begin to unite at one end, it is easy to distinguish that portion which is joined c i b, from that which is not joined c a e, fig. 404.

The sides join so close, that from the first moment no scar can be seen; after which they become compleat polypes, but with a less number of arms, and that in an hour's time, and in twenty-four hours will seize and devour a worm; in a few days other arms shoot and become as long as the rest.

Mr. Trembley cut a polype into four parts length-wise, as follows: after having cut it in two, in the manner just shewn, he cut each of these into two also. These four portions of the same polype, had each of them six arms, within six days after the section; and seven in four weeks; they all eat and multiplied.

When a pregnant polype is cut length-wise, the young ones continue to grow after the section.

He hath also cut a polype length-wise, and directly after cut the same transversely, and each of these four quarters became compleat polypes.

He

He likewise cut another, in part length-wise, beginning at the head, which became a polype with two bodies, two heads ^a, and but one tail. After having nourished this two headed polype, by feeding it at both mouths; he also split these heads, and in a little time it had four, and at last by cutting it after the same manner, it had seven heads, fig. 405.

If a polype be cut in part length-wise, beginning at the tail, it will soon have one head and two tails; and in this manner the number of heads and tails may be augmented by cutting almost ad infinitum.

As all sorts of these fresh water polypes form only a tube or gut, proceeding from one of its extremities to the other, they may be turned inside out as one would turn a sack, viz. give a worm to the polype you would perform this experiment upon, and when it is swallowed, put the polype into a concave glass, or into the hollow of the object-carrying glass, with a little water; afterwards press it near the tail with an hair pencil, stroking it towards the polype's mouth, that the worm within its stomach may be forced partly out, as at c e, fig. 412. its hinder part a, remaining empty. As the worm goes out, the stomach enlarges prodigiously, especially if it goes out double, as is expressed in the figure. When the polype is in this state, make it contract as much as possible, which contributes much to the enlargement of the stomach. It must be here observed, that as the worm is partly out of the stomach it keeps it open, then taking an hog's bristle in the right hand, push it against the extremity of the tail b, till it enters into the stomach, continuing gradually to advance the hog's bristle, till it hath quite turned the polype. When it comes to the worm which keeps the stomach and mouth open, it either pushes that out, or passes by on one side thereof, and at last goes out
of

of the mouth, as at a b, fig. 414. Sometimes the polype is entirely turned at first, and then it covers the end of the bristle a b, fig. 413. In this case the exterior superficies of the polype is become the interior, which now touches the hog's bristle; however it seldom happens that the polype is entirely turned, but most commonly the tail part a b is out of the mouth b, fig. 414. and at the same time a part thereof is not turned; that is, its anterior end a c, which being terminated by the arms, is folded over the turned end. Then to finish the turning, take an hair pencil in your right hand, and the end of the hog's bristle in the left. Always holding the other end of the bristle together, with the polype in the water, and stroke the end a c, which is not turned, very softly with the hair pencil, that way which is necessary to turn it, that is to say, from a to c, fig. 414. which is presently performed, at which time it appears as at a b, fig. 413. Then holding it in the water, push it from a to b, with the point of an hair pencil, and it will fall to the bottom of the glass without being put out of order.

When it is first turned, the mouth closes, and the lips a, incline a little inwards; the arms a c appear to join in a bundle, and to come out of the middle of the polype's mouth, as at a, fig. 415.

After the polype is turned, extend it as much as possible with the hair pencil, then taking an hog's bristle with a knot near one end thereof, run the other end through the polype's body, near its lips; at that instant let the other end of the bristle e, drop into the water, and with the point of the pencil, push the polype to the middle a, of the bristle, fig. 416. then take out the bristle and polype, and put them into a glass, f, e, g, h, taking care that it only touches the glass by its two extremities c and d, that the polype may be a great way from the
bottom

bottom and sides thereof, and the knot end towards the bottom; that if the polype should slide by its own weight, it might not be able to disengage itself. This method is used to prevent the polype from turning itself back into its natural state, which they sometimes do in twenty-four hours after they have suffered this operation; and often after they have been turned, and spitted, to prevent them from returning, they have tore their lips, and by that means have formed two heads.

Several young ones have been produced from these turned polypes, which have also multiplied.

Sometimes they will eat in two days after they have been turned, but generally not till four or five days after.

Most of those Mr. Trembley turned, endeavoured to return themselves again, but could not entirely effect it, remaining like a polype partly turned, as at fig. 406. the skin of its anterior part being applied upon the other, and forming a kind of pad at the anterior end a c, one part thereof being turned, and the other not. Its lips a, are no more at the anterior end, but are round that part of the body which is not turned back again, from whence also the arms proceed, varying their direction, sometimes pointing towards the tail, fig. 406. and at others are bent over the head, fig. 407. their anterior extremity c, fig. 406. formed by the edges of the reversed part c'a, remained open, and some days after began to close; and on being attentively observed, new arms began to shoot near the old ones, and several mouths ^r were also formed near the middle of the bodies of these polypes, that is to say, near the place where their arms joined the body at a, fig. 406.

A polype

^r Hist. de Polype, p. 268.

A polype partly turn'd back again, remains but a little while in that situation, as at fig. 406. The place a, to which this return'd portion a c, was fixed to the other part a b of the body, became a little streighten'd, and the portion a c, formed a right angle therewith, as is shewn at fig. 408. where a c represents the returned portion, and a b the other part of the body; the same day another head appear'd at e, and several arms began to shoot, on one side a o, of one mouth, a o n, which was formed on this side; the other side a n of this mouth, being border'd by part of the old arms a d, a d. Next day the lips of the new mouth was disposed in form of a conical nipple, and the new arms smaller than the old ones. The same day the returned portion a c, fig. 408. which the day before made the right angle c a b, with the other part a b, not returned, was drawn nearer to this last part, and made an acute angle therewith, as at fig. 409. where a c represents the returned portion, and a b that portion not returned. The doubtful part e, remain'd as before; a worm being given to it, fell upon the old arms, was seized, conveyed to the new mouth, and swallowed in an hour's time, and the portions a c, a b, and a e, fig. 409. were swelled with the contents of the worm.

Four days after, its form was much different, as appears by a comparison of the figures 410, and 411, whereof a c, represents the returned part, and a b, the part not returned. Having now but one common mouth a, fig. 410. the new arms are seen between a and t, the equivocal part e as in the figures.

This form was changed but little in fifteen days, as is seen on comparing the two foregoing figures; the old arms which were before between a and t being vanished, and a head at u, fig. 411. which was at first taken for

a young one, but remain'd in the same state above three months. This polype had two young ones, which proceeded one from g the returned part, and the other from f, the portion not returned.

These observations are sufficient to shew the nature of a polype that is partly turn'd back again, and the different revolutions made in these animals, are seen in the figures 406, 408, 409, 410, and 411. which represent the same polype, and the return'd part always a c, and that part not returned a b.

These changes are not exactly the same in all polypes, but vary considerably, seldom any two of a great number being perfectly alike.

The polype represented by fig. 417. was turn'd, and the following day returned part of its head, as at fig. 407. which seven days after was formed into three heads, as at fig. 417. a b, shews the tail of the polype, which remain'd turned. a d c g e, the portion turn'd back again is considerably changed as to form three heads d g e.

Fig. 418. exhibits the same polype fourteen days older, a b the portion which remain'd turn'd, a d c n g e o, the portion turn'd back again, a d, n g, n e, its three heads and necks; marked d, g, e, in the foregoing figure.

Fig. 419. is the same polype thirteen days after it was in the state of fig. 418. The portion o c of fig. 418. is parted from o to c, and the two portions, b a c d o, and c n g e o, fig. 419. are only fastened to each other by a thread o, a b, is the turned portion, a c and o c two portions, which in the preceeding figure are re-united, and marked o c, a d, n g, n e, and are the three heads with necks, and are marked by the same letters, fig. 418.

The two portions held by the thread o, fig. 419. are seen as they were separated in fig. 420, and 421. a b, fig.

420. is the turned part, and a d one of the heads, n g, n e, fig. 421. the two other heads.

Mr. Trembley imagined, that if one polype could be put in the stomach of another, in such a manner, that the external superficies of the skin of the first, should be applied to the internal superficies of the skin of the second, they might stick together, and become but one polype.

To introduce one polype into another, first feed some of them, and when they are swelled by the aliments, their mouths will be also extended. Take that polype out of the water, you would introduce into the stomach of another, and put it upon your left hand, making it contract as much as possible by stroking it with an hair pencil, in such a manner as to force the aliments out of its stomach, and thereby cause its mouth to open; then taking a hog's bristle in the right hand, put the biggest end thereof into the polype's mouth, and thrust it to the bottom of its stomach. When this is done, place the polype upon your hand, into which this is to be introduced, causing it to open its mouth, as in the other polype, and thrust that which is upon the hog's bristle, into the stomach thereof, and dip it into a glass of clean water, that you may examine it with a magnifying glass; then to prevent the inner polype from extricating itself, spit them both together upon an hog's bristle.

Fig. 422. represents two polypes put one into the other, a b the exterior polype, and c a, b d, the interior one; e f in all the figures shews the hog's bristle which run through both the polypes at e.

Fig. 423. is the same polype, a i b the exterior one, c a i d the interior one; the part i d by bending having ript up the part i b of the exterior polype, and by this means got out.

Fig.

Fig. 424. shews the same two polypes, whereof *i d*, of the interior, tore the part *i b* of the exterior one farther up, even to *e*; where the bristle at first ran through both the polypes together: but when in the state represented by this figure it pierced the interior one *c a i d* at *e*, and the exterior one *a i b* at *i*.

Fig. 425. represents the same two polypes after the anterior one *a e b*, had tore up the lips of the exterior one, *c e d*, and came out therefrom; they were separated in a few days, and both of them did well.

Mr. Trembley hath given us a curious drawing of an aquatic animal which he calls a plumed polype; it is represented as they appear in the microscope at fig. 426. The plume and length of its body taken together are about two twelfths of an inch in length, its body very small, almost cylindrical, and skin perfectly transparent. The plume is a continuation of this transparent skin, very large in proportion to its body, and of a very remarkable figure.

Its base *e a c* is in the form of an horse-shoe, from the edges of which proceed the arms *a d*, *a d*, *a d*, whose extremity is a little turned outwards, and are so close together, that the plume contains 50 or 60. The base *e a c* of this plume serves the animal for a mouth; its intestines may be distinctly seen through this transparent skin at *e b*, *f g*, *f a*, and are of a brown colour; after the animal hath eaten, three principal parts of their intestines are visible, the gullet *e b*, the stomach *f g*, and the strait intestine *f a*.

These animals withdraw themselves into a case *i, k, l, B, I, m*, that seems to be composed of the same transparent matter with the skin of the body, which is fastened by its inferior extremity *i b, I B*, to the orifice of the case; so that whenever the animal retires into the case,
the

the skin of the body is reversed. The plume which is upon the base c, enters with it, and appears, when all inclosed, like A B. After it is thus inclosed, it will soon come out again if it be left quiet.

When it is out of the case, you may see a tendon fixed by one end g, to the inferior extremity of the stomach; and the other at o, the bottom of the case. There is also another of these tendons fixed to the base of the plume at a, and the other end of the same to the bottom of the case at o; it is by the help of these two tendons that the animal draws itself into the cell.

These plumed polypes are seldom alone, but many of them placed together one by the side of the other; and there are several of them that come out of the same case, but by different orifices, which is the way they multiply.

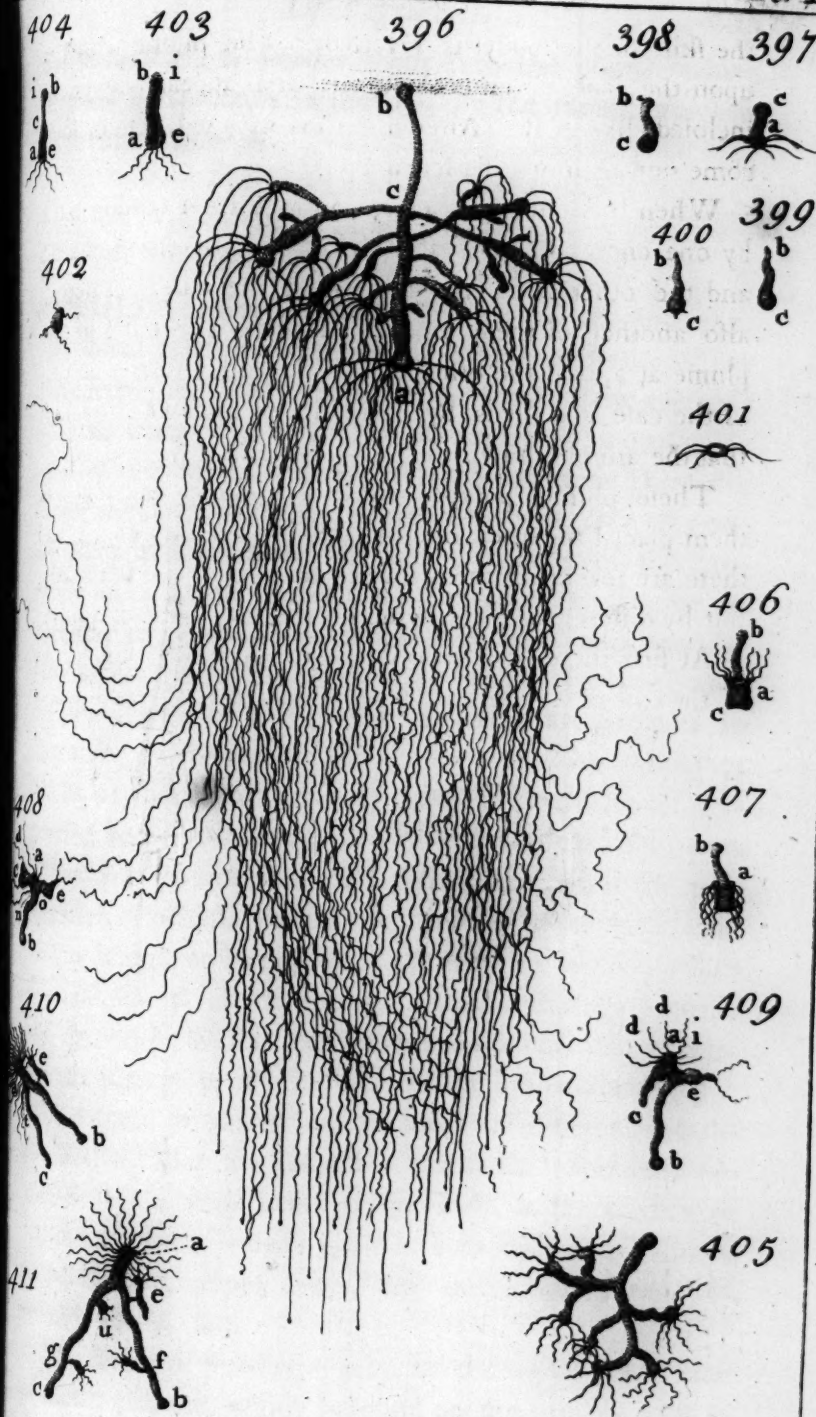
At first there is a little elevation upon the superficies of the case of an old one, after which the body and plume st begin to appear; or when a young one begins to shoot the base of the plume and points of its arms u u u, shew themselves and increase as the body enlarges.

They can only eat very small animals, but of these they devour great numbers in a day.

The quick motion of the plume, or rather the feather-like arms thereof, form a kind of whirlpool, into which most of these little animals that are swimming near it are precipitated.

Every instant one or two of its arms suddenly bend into the plume, and immediately replace themselves into their first situation; the same arm seldom bends twice together, nor do they touch the prey but by their rapid and continued motion cause a turning in the water, which conducts those minute animals into the plume, although they make several efforts to escape, the sudden inflection of one arm, adds a new degree of rapidity to

the



Bowles sc.



the torrent which hurries them into the plume, where they are immediately swallowed, by the mouth which is in the midst thereof.

Of vegetables.

THIS seemingly inferior branch of the creation, when carefully attended to, by the assistance of the microscope, exhibits to us an ample scene of the creator's wisdom, curiosity, and art, in the wonderful contrivance even of the most abject vegetables, but more especially in the anatomy of them; wherein may be seen the admirable provision made for the conveyance of the lymphatic and essential juices, in communicating the air, as necessary to vegetable as animal life, and more particularly in the generation and make of the seed, wherein the lineaments of the parent vegetable are inclosed in miniature; and wherein also we see that God Almighty has by one act of his creating power provided for all succeeding ages; and the future posterity of each seed does of necessity produce its own resemblance: for the preservation of which, nature hath endow'd some with light downy wings, to be conveyed about by the winds; others are laid up in elastic springing cases, that upon bursting dart their seed at convenient distances, and others, &c. are planted by the industry of the husbandman.

The seeds of plants are inclosed in different sheaths or cases, till they are lodged in the earth. Some are deposited in the very heart of the fruit, as the kernels of apples and pears, others grow in cods or shells, as peas, beans, lentils, poppy seeds, and cocoa nuts; some in wooden shells, &c.

The farina of flowers appears to the naked eye a kind of mealy powder, which is found on the pendant tops of

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almost

almost every flower; its colour various in different flowers, but its structure constantly the same in plants of the same species. Here also the microscope hath discovered surprizing beauties, and hath shewn us, that this powder is produced with the utmost care in vessels wonderfully contrived to open and discharge it, when it becomes mature, and that there is a pistil, seed-vessel, or uterus, in the center of the flower, ready to receive the minute grains of this powder, either as they fall of themselves, or are blown out of their little cells. We are also taught by experience, that the fertility of the seed entirely depends on this; for if the farina vessels are cut off before they open and shed their powder, the seed is unprolific *.

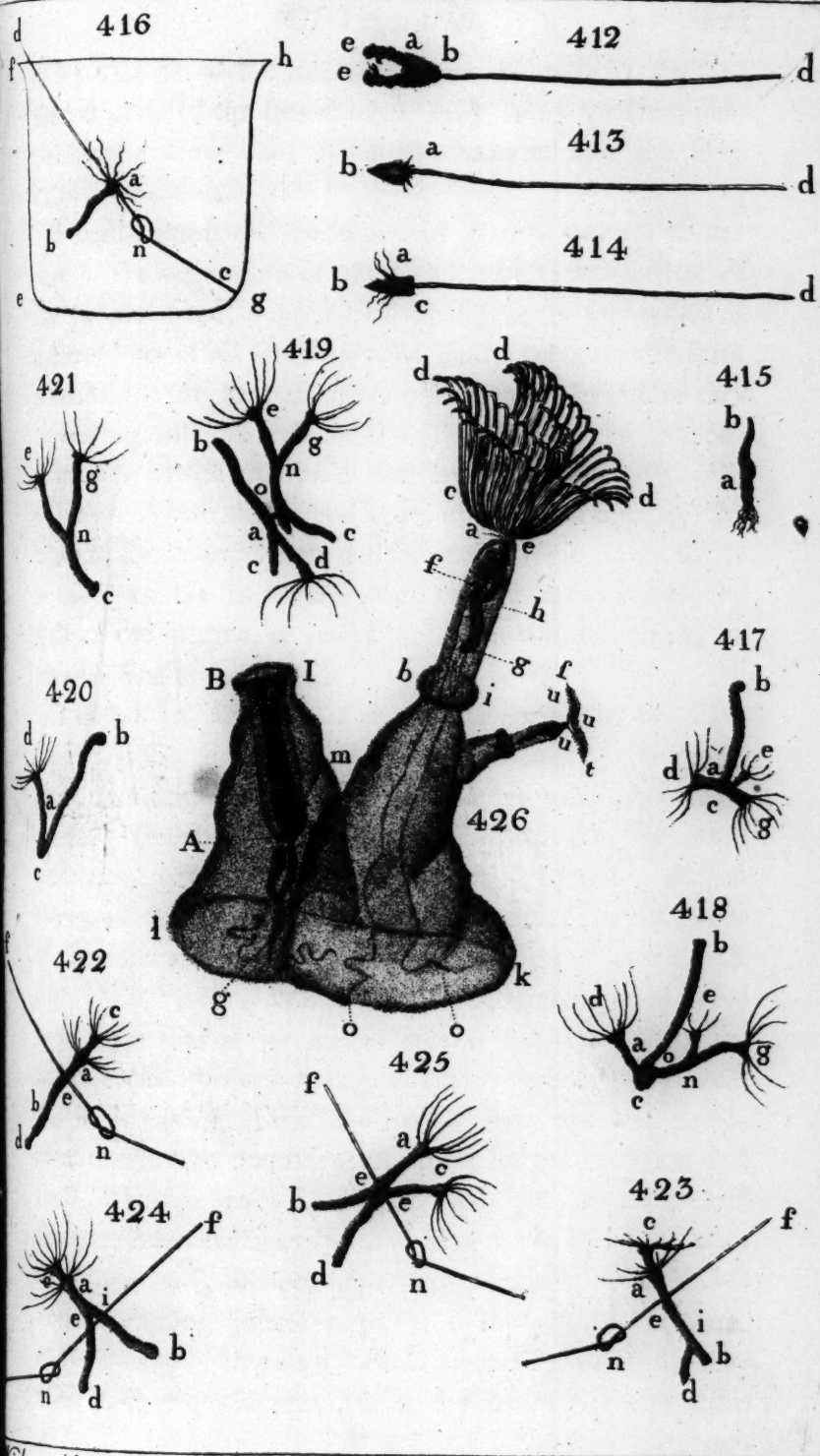
Of seeds.

THE seed is the last product of a plant whereby the species are propagated; it is frequently the fruit of the plant, as is the case in most herbs: sometimes it is only a part inclosed in the fruit, and that in form either of grain, kernel, or berry.

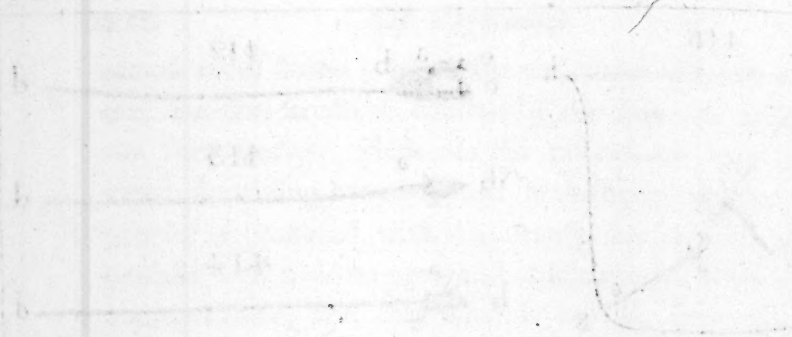
It is the natural offspring of the flower, and that for whose production all the parts of the flower are intended; so that when this is once well formed, the several parts of the flower dwindle and disappear.

It is produced from the farina of the apices let fall on the head of the pistil, and thence forwarded to an uterus at the bottom thereof, divided into several cells; where coming to receive the nutritious juice of the plant, it is first softned, then swelled, increased both in matter and bulk, and at length comes to its state of maturity.

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By the use of the microscope we discover in the seed several parts of the future tree, only in miniature; particularly a little root called the radicle, and the stem called the plumule.

I shall exhibit the curious and gradual process of nature in the vegetation of the seed; and first, in that of the garden bean, represented by fig. 427. by which a general idea of all seeds may be easily formed. It hath a small hole at *a*, that upon dissection is found to terminate against the stalk of the plumule; its end is apparent at *a*, in the transverse section of the bean, fig. 428. in which figure the several coats of the bean appear, the innermost is every where twice, and in some places thrice as thick as the outermost; and where it surrounds the stalk of the plume, it is six or seven times as thick, as may be seen at *b*, fig. 428.

The hole *a*, fig. 427. is not casually made by breaking off the stalk, but design'd for the nurture of the young plant, and may be seen in several other kinds, as peas, vetches, french beans, lupines, lentiles, &c. in other seeds also, medica tornata, fænugreek, goats-rue, &c. in several of these it is not discernable without the assistance of the microscope; and in some not without cutting off part of the seed. When any of the above-named seeds have been soaked in water, several bubbles will alternately break through this hole on their being squeezed. All seeds having thick and hard covers, are also perforated in the like manner; and those lodged in stones and shells, though not visibly perforated, yet the stones and shells themselves always are. When the coats of the bean are stripped off, the seed appears; its main body is divided into two lobes, joined together at the base of the bean, as at fig. 429. In young beans, especially if boiled, these lobes easily slip asunder; but in dry beans are very diffi-

cult to be separated, unless they be first macerated for twenty-four hours in water. Some few seeds are divided into more lobes, as the cressies into six, and some not at all, as grains of corn, &c. most other seeds, even the smallest, are divided exactly into two lobes like the bean; that which joins the two lobes together is called the stem or radicle, out of which the root is formed when the seed vegetates. This stem is found in all seeds; in the bean and several others, it is situated somewhat above the thick end, in oak kernels, commonly called acorns, apple-kernels, almonds, &c. it stands prominent just from the end.

The plume or bud issues out of this stem, and is that which afterwards becomes the trunk of the plant, separable in several already formed, though not displayed, leaves, which appear upon the sprouting of the seed, and may be seen in the seed itself by the assistance of the microscope.

The plume is inclosed in a cavity formed in the lobes on purpose for its reception, which may be seen at b, fig. 429. it is almost of the same colour with the radicle, or little root, on the basis whereof it is sustained.

It is the first part that appears out of the earth; as in effect it is the first part that appears out of the membrane, or cover of the seed, there being a hole over against it in the membrane, through which it makes its escape.

It is the appearance of the plume without the cavity of the grain, that makes what we call the bud or germ of a plant.

In dissecting a bean, if you hold your knife aslope, and very gently bear upwards, an exceeding thin and transparent skin will shew itself, just as the knife enters; this skin is not only spread over the convex of the lobes, but also upon the flat thereof, and is extended both upon
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the radicle and plume, and so all over the bean. This fine skin vegetates imperceptibly, and the two extremities of the bag, which surround the head of the bud, expand and rise with it in order to preserve it from all such frictions as may injure its tender and delicate texture *. Next to this is the parenchyma, consisting of an infinite number of extremely small bladders, which may be seen in a very thin slice of a bean when applied to the microscope, and appears like pith while sappy in the roots and trunks of plants; on cutting the radicle transversly in several parts, another body of a quite different substance from the parenchyma or pulp, will be found, which is also conspicuous in a transverse section of the lobes, and appears there like several small specks, and of a different colour from the pulp: these are the several branchings of the tubes proceeding from the radicle, and forming but one intire trunk till it rises to a b, fig. 430. from whence it issues forth into three main branches, the middlemost directly into the bud c, and the other two after a little space, pass from e e on either side into the lobes, where they divide into smaller branches, and these again spread into other more minute ramifications, and terminating near the verges of each lobe, become a perfect root.

This seminal root being so tender, is difficult to be discovered, but may be come at by a careful paring off the parenchyma in thin slices lengthwise, in new beans; or if old beans are soaked a considerable time in water, the same may be effected.

The specks that appear on cutting the radicle and plume transversly, are most visible in the bean and great lupine.

The seminal root hath not yet been discovered in apples, plumbs, nuts, &c. partly from their colour, being the

P 3

same

* Grew Ana. Plant. p. 4.

same with that of the pulp, yet in the gourd seed the main branches with their several ramifications appear immediately on separating the lobes.

The parenchyma of the lobes is a kind of meal intermingled with a nutritious juice, or sap of the earth, forming a kind of pap or lacteous substance, which being filtered through the several branchings of the seminal root, are conveyed through the two small tubes a and b, fig. 430. into the bud, which is gradually replenished therewith. When these seminal roots have communicated all the nourishment of the lobes to the young plant, they begin to wither, together with the skin that covers them; the stem or radicle then also begins to take root in the ground for its future subsistence.

The coats of the seeds.

HOW it was in its state of vegetation hath just been shewn; it remains then to inquire into its state of generation; for what in the other state was not apparent, or intelligible, will in this occur; and here also we shall find a large field for the employment of the microscope.

The two general parts of the seed are its covers and body. The covers in this state are usually four; the outermost, which is called the case, and is of various forms, sometimes a pouch, as in nasturtium, cochlearia, &c. a cod, as all pulse; sometimes parted as sorrel, knotted grass, &c. The two next are properly the coats, in a bean especially, and the like; from whence the denomination may run to the corresponding covers of other seeds; their figures are sometimes kidney'd as alcea, behen, poppy; triangular, as polygonatum, sorrel, &c. spherically triangular, as mentha, melissa, &c. circular, in leucioium, amaranthus; globular in napus, asperula;
oval

oval in *speculum veneris*, *tithymalus*; semi-globular in coriander, semi-oval in anise, fennel, pirimidal in *geranium*, *althææfol*, with many other differences.

Sometimes glistering, as in *Venus* looking-glass, rough cast in *catanance*, studded in *behen*, *blataria*; favous in *papaver*, *antirrhinum*, *lepidum*, *annum*, *alcea-vesicaria*, *hyoscyamus* and many more, " before the seeds have lain long by; pounced in *phalangium cretæ*, *lithospermum*; ramified in *pentaphyllum fragiferum erectum majus*, resembling the fibres of the ears of the heart.

All seeds have their outer coats open, as in beans and pulse, as before shewn, or else by breaking off the seed from its peduncle or stool, as in cucumber, chicory, &c. or by the passage of a branch or branches, not only into the concave near the cone or top of the seed, but through the cone itself.

The fourth or inmost cover, is called the secondine, a sight of which may be obtained by cutting off the coats of an infant bean in very thin slices; at the cone thereof, if not broke, it is transparent; if torn, it gathers up into the likeness of a jelly. In large old beans it is not to be distinctly seen, but in most seeds it may, even when full grown, as in cucumber, colocynthis, burdock, *carthammum*, gromwell, endive, mallows, &c. though in these it is generally thin and difficult to be discovered, yet in some kernels, as apricocks, it is very thick, and remarkably so in some other seeds.

The concave of this membrane is filled with a most transparent liquor, out of which the seed is formed, as appears on cutting an infant bean, or better in a young walnut.

Through this membrane, the lignous body, or seed-branches, in the inner coat, shoot down in two slender

P. 4 fibres,

fibres, near the base of the radicle, one into each lobe of the bean, and there spread into a great many ramifications, which convey the juices on the vegetation of the seed, into the radicle and plume, as before described.

Of the seed cases or membraneous uterus.

THE seed case is a kind of fleshy uterus, growing more moist and pulpy as the seed ripens, but the case itself whether called cod, pod, or by any other name, is a membraneous uterus, which grows more dry and hard as the fruit ripens. In some the seed case is originally open, in others it opens when the seed is ripe, and in others not at all till the seed is sown.

Garden radish-seed breaks within as it ripens into several white dry membranes, round about the seed. Near the sides of the case run a pair of vascular fibres, from which branch forth several smaller fibres, some towards the sides of the case for their support, and others towards the center thereof upon which the seeds hang, fig. 431.

Of those which open as soon as the seed is ripe, some open at the top, as poppy heads, fig. 432. others on the side, as most cods; and some at the bottom as coddled arsmat, fig. 433. the poppy head is divided by eight or ten partitions into as many stalls, and on both sides the partitions hang a most numerous brood of seeds.

Of those which open on the side, some open on one side, some on both, others with three sides, some more, and others horizontally, or round about.

The cod of a garden bean opens on one side, and hath a two-fold parenchyma; in the outermost stands all the vessels in several parcels, from one of which, being larger than the rest, and at the back of the cod, shoots forth these lesser vessels whereon the beans grow; the inner
pulp

pulp is wholly composed of bladders, in which many of those threads whereof the bladders are wove, are so loose, as to be easily drawn out to a considerable length, and are very visible when applied to the microscope.

The seed case *a b c d*, of yellow henbane, fig. 434. opens on both sides, from its top at *a*, grows a stem, which diminishes as the case swells, and at last falls off. On the sides of the case run two opposite vascular fibres, and as the case gradually increases, it as gradually separates on both sides in the tract of the aforesaid fibres as at *b*. The case is lined with a smooth thin skin, in whose center is a great parenchymous boss *c*, being the bed of the seeds which lie all over as in a strawberry; throughout this bed the vessels *d*, for the generation and nourishment of the seed, are distributed, as may be seen in the transverse section thereof at *d*, in which a very small fibre, shooting from the direct fibres obliquely into each seed, is plainly visible.

The seed case of a tulip, whereof *a*, represents the case intire, *b* is a transverse section of it, and *c* the case split down. Fig. 345. it opens on three sides, from the midst of each proceeds a partition, all meeting in the center of the case, and making six divisions for the seed. The vessels are curiously disposed after they rise above the stalk, being at first divided into three principal branches, running along the three angles of the case, from which divers lesser branches tend horizontally, and meet at the middle of each side; whence they proceed through the breadth of each partition to their edges, in the center of the case, where they are again distributed into very fine and short threads, whereon the seeds hang.

The seed of anagallis or pimpernel, fig. 436, is a little globe opening horizontally into two hemispheres, the uppermost

uppermost falls off when the seed is ripe, and so the wind sows them.

The seed-case of coddled arimat, fig. 433. neither opens at the top nor on the sides, but at the bottom, being composed of four sides; in the center of the case, is a column a, upon which the seeds hang loosely. From this mechanism that violent ejaculation of the seed is intelligible, which is not a motion in the seeds themselves, but contrived by the structure of the case, the seeds hanging very loosely, not on the sides of the case, but on the stem in the center thereof, with their thickest ends downwards, standing ready for a discharge; the sides of the case being lined with a strong membrane, they perform the office of so many little bows remaining fast at the top b, are let off at bottom, and forcibly curl upwards and drive all the seeds before them.

Of the number and motion of seeds.

Nature hath procured the propagation of plants several ways, but chiefly by the seed; for the production of which the root, leaves, flowers and fruit do all officiate; and according as the plant or the seed it bears is more or less liable to be destroyed, provision is made for the propagation of either by a greater number of seeds, or otherwise; for instance, the seeds of strawberries being gathered, or eaten by vermin with the fruit, the plant thereof is easily propagated by trunk roots; the white poppy being an annual plant is highly prolific, commonly bearing about four mature heads, in each of which are at least ten partitions, on both sides whereof the seeds grow, and on one fourth part of one side, about a hundred seeds, that is eight hundred on one partition, which multiplied by ten makes eight thousand, and this multiplied

multiplied again by four, the number of heads, gives thirty-two thousand seeds, the yearly product of that plant.

So also in *typha major*, the seeds being blown off and sown with great hazard, are prodigiously numerous, they stand altogether upon the spike, and make a cylinder at least six inches long, and near five eighths of an inch in diameter. Nine of these seeds set close together upon a right line make but the eighth of an inch, so that seventy-two make a line of an inch in length; but because upon the spike, the hairs belonging to the seed come between them, we will abate ten, and count but sixty-two; to which if three fourths be added (abating the fraction, viz. 46.) makes a hundred and eight, for the circumference of the cylinder, which being six inches long, there are six times sixty-two for a line the length of the cylinder, which is three hundred seventy-two; which number being multiplied by a hundred and eight, produceth forty thousand one hundred and seventy-six, the number of seeds that stand upon one stalk: therefore upon three stalks which one plant commonly bears, there are in one year a hundred and twenty thousand five hundred twenty-eight seeds.

As soon as the seed is ripe, nature taketh several methods for its being duly sown, not only in opening the uterus, but also in the make of the seed itself; for first the seeds of many plants which effect a peculiar soil, as arum, poppy, &c. are heavy and small enough without further care to fall directly down into the earth, and so to grow in the same place where they had their own birth. But if the seeds are so large and light as to be exposed to the wind, they are often furnished with one or more hooks, to prevent their wandering too far from their proper place, till by the fall of leaves or otherwise, they are safely lodged.

The

The seeds of avens have one single hook, those of agrimony and goose-grass many, both the former loving a warm bank, and the last a hedge for its support; on the contrary, divers seeds are furnished with wings or feathers, partly with the help of the wind to carry them when ripe from off the plant, as those of ash, maple, orach, &c. lest staying thereon too long, they should either be corrupted, or miss their season, and partly to enable them to make their flight more or less abroad; that by falling together, they may not come up too thick, and if one should escape a good soil or bed, another may light thereon. The kernels of pine have wings, not unlike those of some insects, but very short; in respect of the weight of the seed, they do not fly into the air, but only flutter about upon the ground; those of typha dandelion, and most of the papous kind, with many more, have very long and numerous feathers, by which they are wafted every where, and to any convenient distance.

Some seeds are scatter'd, not by flying abroad, but by being spurted away as wood-forrel, fig. 437. which is effected by a white, thick and strong cover of tendons of a springy nature, in which the seed within its case is inclosed. This cover, as soon as it begins to dry, bursts open in an instant, on one side, and is violently turned inside out, and so smartly throws off the seed.

The seeds of harts-tongue, fig. 439. and all that tribe, are flung or shot away by a curious contrivance in the seed-case; as in coddled arsmart, or other like plants, only there the spring moves and curls up inwards, but here it moves outwards; every seed case stands upon a little pedicle, a a a, fig. 439. being of a silver colour, and of a spherical figure; it is girded about with a strong tendon or spring a, (whose surface resembles a fine screw, of a golden colour, which breaks the case, immediately upon
its

its becoming elastic enough) into two hemispherical cups, as at *bc*, and by that means sling off the seeds. These cases grow in furrows, *de, de, de*, on the back of the leaf, as at *fig. 438*. in one of which of an inch long, are more than three hundred of the above-mentioned cases; and allowing ten seeds to every case, makes three thousand seeds; which multiplied by the number of furrows in one leaf, with allowance of the lesser furrows, and that sum by the number of leaves commonly growing upon one root, amounts to above a million of seeds,* the annual product of this plant. The seed is of a tawny colour, flat and somewhat oval; of these ten thousand are not so big as a white pepper corn. *Fig. 439*. represents a few of the seed-cases magnified; they were cut out of the furrow at *f*, in the leaf represented by *fig. 438*.

Divers notable means of semination are observed by other authors. Mr. Ray tell us, that a quantity of fern seed, laid in a lump, on a paper, the feminal vesiculæ are heard to crackle, burst, and, by the microscope, the seeds are seen to be projected to a considerable distance from each other.

Dr. Sloane observes, that the gentianella flore cæruleo, or spirit leaf, requiring wet weather to be sown in, as soon as the least drop of rain touches the end of the seed vessels, with a smart noise, and a sudden leap, it opens itself, and with a spring scatters the seed.

Other plants sow their seeds by inviting birds by their agreeable taste and smell, to feed on them, swallow them, and carry them about; thereby also fertilizing them, by passing through their bodies. In such manner are nutmegs and mizzletoe sown and propagated.

Of

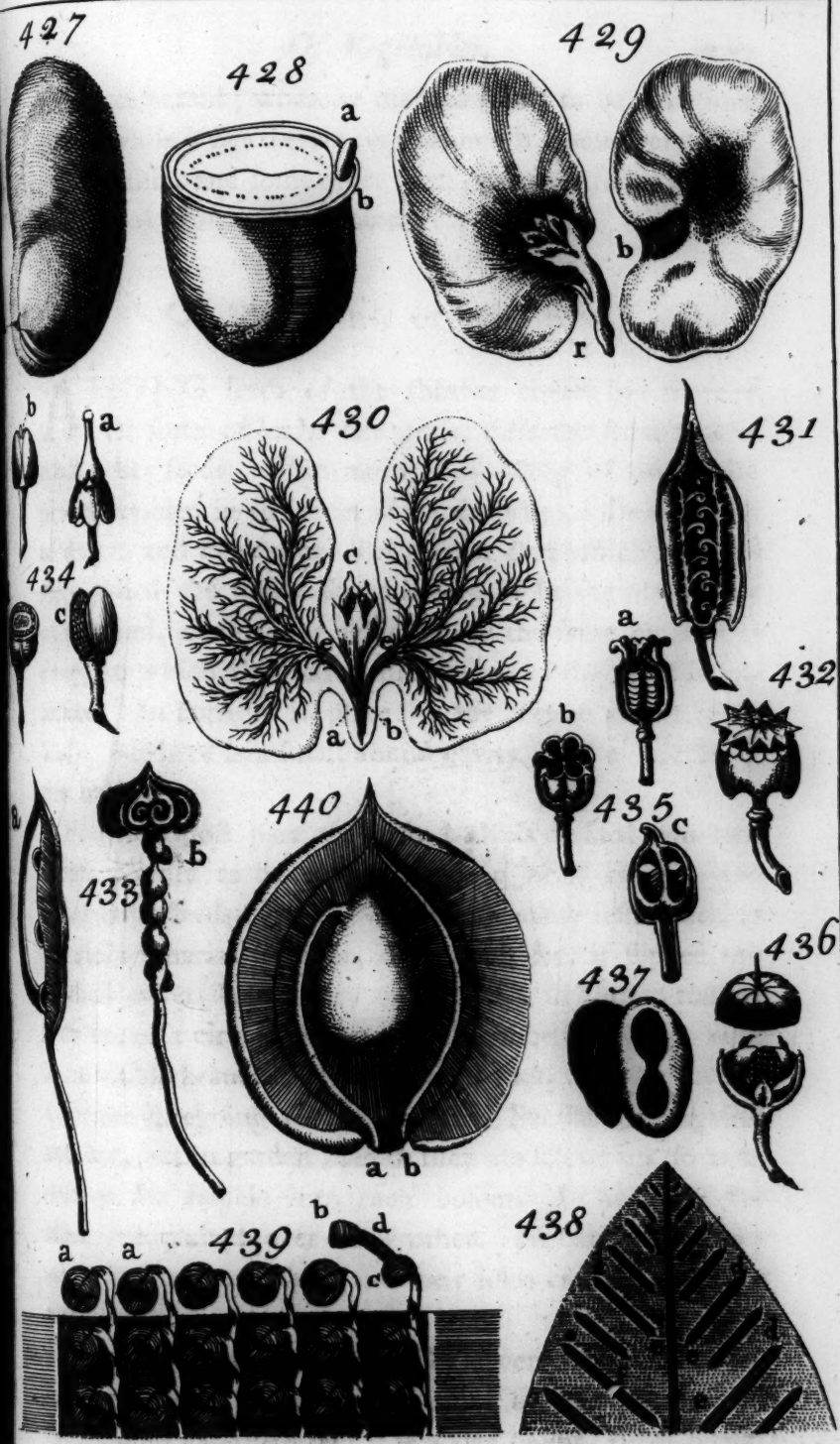
* Grew. Ana. Plant. p. 119

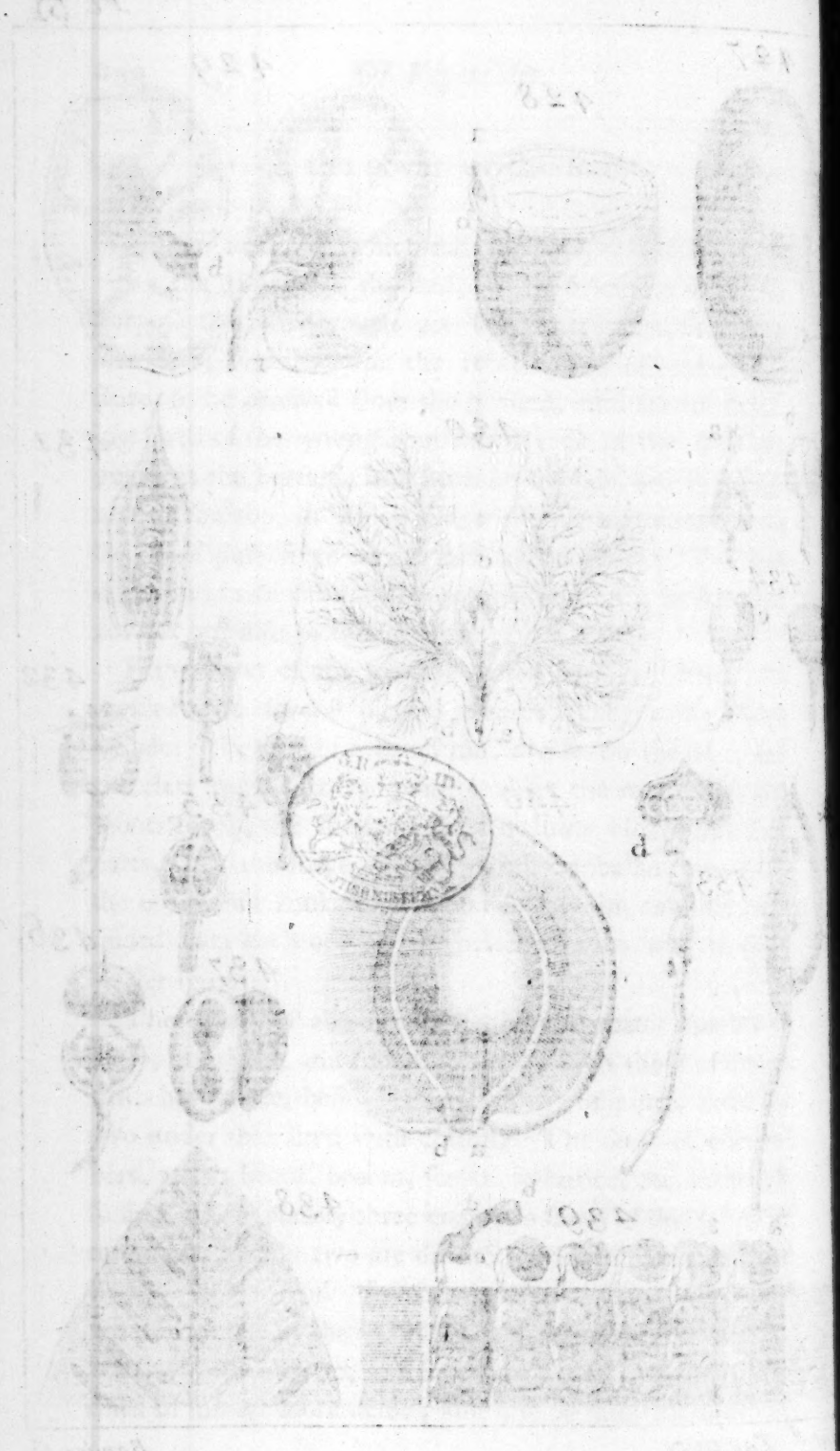
Of the cover of the feeds.

THE next step which nature takes, relates chiefly to the growth of the seed, when sown, and for this purpose the outer covers are somewhere furnished with apertures, sufficient for the reception of alimantal moisture, to be received from the ground, and for the shooting forth of the young root into it; as in the seed of a gourd at the bottom, in a bean on the side, and in a chestnut at the top, in which place the young plant always lies, and puts forth in the said several feeds. The seed of palmi christi falls to the ground, not only in the usual covers, but also in the said case.

If the cover of the seed be stony, and very hard, it is divided into several pieces, whereby they easily cleave asunder: the shell of a hazel nut, divides on the edge, and the cleft begins at the point, where the root stands and shoots forth; the shells of some walnuts cleave into four parts, and the stone of bellerick myrobalan into five: the covers and husks of some sorts of grain, as millet, are folded over each other, the better to give way to their tender sprouts.

The covers of all, or at least the far greater number of seeds, are three, and sometimes four, even those of stoned fruits have three, besides the stone; in gossipium, there are two under that lin'd with cotton. The seeds of cucumbers, goat's beard, broom, scabious, lattice, &c. although so small, have plainly three coats; in some of these, and in many more, only two are distinctly visible, except in the state of generation. In the upper coat the seed-vessels are disseminated; the second is at first a mere pulp, which afterwards shrinks up, and sticks close to the upper. The third or inmost more dense; and if it be thin, for the most part





part transparent; whereby the seed seems to be sometimes naked while it lies therein, as in almonds, cucumbers, &c.

In melissa, and some other seeds, it comes finely off, on being soaked in warm water.

Of the foetus, or true seed.

AMONG seeds of the thinner covers are those of all sorts of corn and grass, different from that of most other seeds. The main body being of one entire piece, doubled in the form of a pair of lips. In the seeds of dates, and some other like plants, that which is generally called the stone, seems indeed to be the main body of the seed, doubled or folded up in the same manner as corn, to which that part which becomes the plant is annexed. In corn it is placed in the bottom of the main body, but here is a small round cavity in the middle of the back.

For the most part the main body is divided into two lobes, plainly to be distinguished in most kernels, and other large seeds, and not difficult in many lesser ones, as in *viola-lunaris*; scabious, doves-feet, &c. if slipped out of their covers before they are full ripe; in hounds tongue they are of a circular figure; in cucumbers, oblong, with some visible branches of the seminal root, &c.

In the foregoing seeds, the lobes lie flat one against another, but in garden raddish they are folded up, so as to receive the radicle into their bosom. In holy-oak the lobes are plaited over each other. In cotton seed they are very broad and thin; and their folds curious and very numerous.

Many of the seeds, with bulky covers, are not divided into two lobes, being in a manner of one piece, as all the bulbous kind: in flag it is above twenty times bigger than

than the seed within it, and consists of bladders radiated towards the seat of the seed, and these disposed in parallel lines running lengthwise.

But the greatest number of seeds with bulky covers, are divided into two lobes. In the purging nut of angola, if the shell be taken off, the upper covers, (dried and shrunk up) seem to be but one: in these the spermatie vessels are branched, and under them the thick and inmost cover; which being cut down the middle thereof, shews the true seed, consisting of two veined leaves, as white as milk, joined together with the stem or radicle at their base, and sunk into a hollow made in the cover. The same is also observable in the Barbadoe nuts, ricinus, Americanus, and some other Indian fruits.

In the foregoing fruits, the bulky is very soft, but in *nux vomica officinarum*, it is nearly as hard as a date stone; in this, and the foregoing, the seeds are large, but in others are so small, that they are scarce discernable without a microscope, as in *staphisagria*. The thick or inmost cover is conical towards the base, at whose point is a little cavity where the seed is lodged; the root thereof pointed, and lobes rounded at the top. In peony the same cover is soft, white, and of an oval figure, the part used for medicine is thought to be the seed itself, but is near two hundred times bigger than the true seed; which lies in a little cavity near the bottom of the cover, with a blunt root, and two pointed lobes.

In coffee-berries, the seed lies in the inner cover, near the top; the back of the lobes are veined like two minute leaves, and joined to a long root.

The seed of *stramonium* is inclosed in a bulky cover, which being soaked in water, and carefully cut about the edges with a sharp razor or penknife, its seed may be taken out entire, and examined by the microscope.

Of the buds of seeds.

THE stalk of the plant rises up from between the lobes, which may always be seen, in some by the naked eye, and in others by the microscope; in many plants nature sees fit only to lay the foundation thereof in a round node, as in *viola lunaria*, &c.

But in most seeds is formed a true bud, consisting of perfect leaves, in some two, others four, &c. In bayberry only two, very small, but thick, and finely veined; in the seed of *carduus benedictus*, they are also two, pointed at top, and situate a little distance from each other, for the two next to rise up between them.

In some herbs, although the bud consists but of two perfect leaves, yet they are very conspicuous, not only in the larger seeds, as *phæscolus*, or French beans, but in small ones too, if examined by the microscope, as in the seed of hemp. A B, fig. 441. in which the two leaves are plaited, and set edge to edge, c shews the other part of the seed which was separated to lay the bud fair to view. In the seed of *senæ*, the bud hath four leaves: in the seed-bud of an almond C, D, fig. 442. there are six or eight, and sometimes more distinct leaves visible, if by a dextrous separation of the outer, the innermost are laid open, they are folded inward one over the other, as appears at D, which represents them open, and at C the same seed-bud is seen shut.

The lobes of the seed, and so likewise the stalk and bud, consist of a skin, parenchyma and branched vessels, as before described; all which are apparent to an eye armed with a microscope.

The first skin, as in French-beans, may be easily separated from the parenchyma, especially if the bean be soaked in water for some days, it will slip easily off, and will be found to consist of bladders, smaller than those of the parenchyma, and intermixed with a kind of lignous fibres which give a toughness to the skin. The branched vessels run through the parenchyma, and compose the seminal root in the lobes, being no where extended to the circumference of the lobes, but are all inosculated together at a considerable distance from it; all meeting therein in one solid nerve, but in the stalk are dilated into an hollow trunk, filled with a pith composed of bladders, which in the stalks of French beans is very conspicuous; they consist of sap and air vessels as the other parts of a plant, not running collateral, the latter being sheathed in the former, and are plainly visible in the microscope.

Of the generation of the seed.

AS a garden bean was chose to shew the manner of the seeds vegetation, so an apricock is very fit to observe and represent the method nature takes in its generation.

A proper uterus is first prepared, both to keep the membranes of the foetus warm and succulent, and to preserve and secure it afterwards till it takes root in the ground. For this purpose both the pulp and stone of the fruit are necessary; but first the stone, the pulp being only necessary to form the stone, the petrifying of that parenchyma which is the ground of the stone, being effected by the sinking of the tartar * thereinto; for

It

* Grew. An. of Plants, p. 209.

It is evident on cutting a young apricock, and then with a sharp razor shaving off a thin slice, and viewing it through the microscope, that at first the ground of the stone is a distinct and soft parenchyma, composed of bladders, as the pulp itself is, which bladders, as they harden into a stone, fill up and disappear.

This parenchyma takes its rise from the pith, as the pulp does from the bark, and composes the greatest part of the stone; its inside is lined all over with a thin skin, covering the seed branch on its first entrance into the hollow of the stone; which skin is also composed of exquisitely small bladders, by which means it soon becomes a very hard and dry body.

The stone being made hard and dry, could never be sufficiently softened (to give passage for the vegetation of the seed) by lying under ground, did it not easily cleave in two; for which purpose the skin of the fruit is immediately concerned; for in a transverse slice of a young apricock, if it be cut with a sharp knife, this skin may be seen (when applied to the microscope) fairly doubled inwards from the two lips *a b*, *a b*, of the fruit, fig. 443 and 444. and from thence continued through the pulp and stone itself into the hollow thereof, where it meets and is united with the lining before-mentioned; and as it conduces towards the drying of the stone, so also it renders it cleaveable in that part where it runs through it.

Nature having thus provided a convenient uterus, her next care is about the membranes of the foetus, these are three apparently distinct, and in many respects different from each other.

The first of these, fig. 443. represents a transverse slice of a young apricock near the lower end, shewing the duplicature of the skin half way through the stone. Fig. 444. a transverse slice cut through the upper end, shewing

the duplicature of the skin quite through the stone; and at e f, fig 446. is shewn the branches which run through the stone to the flower and seed, in a well grown apricock cut lengthwise.

The outermost of these membranes takes its rise from the parenchyma, and surrounds the seed branch, and upon its entrance into the hollow of the stone is expanded into two bladders, one within the other; whereof one becomes the lining of the stone, the other the outer membrane, and is best seen on cutting a young apricock when it is about half an inch long through the middle, or from the seat of the flower to the stalk, between the two lips a b, fig. 443. At this age the outer membrane hath a full and firm body, and is composed of bladders, as may be plainly seen on its application to the microscope.

The vessels contained in the seed branch, are distributed throughout this membrane, beginning a little below its smaller end, and running round both ways, meet in the middle of the greater, where they are all inosculated and form a kind of umbelical node, as at a, fig. 445. from whence they strike deeper into it till they arrive at the middle membrane, where they become invisible; these vessels convey the sap to the middle membrane, whose bladders are more angular and amplified towards the center, being at least two hundred ^z times bigger than those of the outer membrane.

This middle membrane is so called from the state and condition it hath upon the augmentation of the seed, at which time it obtains the name of an involucrum ^a, but originally is every where entire without any hollow, filling up the cavity of the outer membrane like a soft and delicate pulp. After a short time a small channel appears therein, running from the bottom to the top; at first no wider than to receive a human hair, and then only

^z Grew. An. Plan. p. 210.

^a Ibid.

only visible in a transverse slice, and that not without a microscope; but when grown a little wider, may be seen if the membrane be carefully cut lengthwise, at which time it is dilated into two oval cavities, *e f*, fig. 446. one at each end, into which a most pure lymph continually owzeth, and is therein reserved for the nourishment of the seed, and also passes freely from one to the other.

A few days after this, the inmost membrane begins to appear like a soft bud growing out of the upper cavity, being joined to its lower end by a short and tender stalk; from whence it is produced into a conical oval figure, answerable to that marked *g* in the cavity, fig. 447. This membrane, though soft and full of sap, is composed of bladders, three hundred times smaller than those of the middlemost, by which means the seed is so well guarded, as not to be supplied with any other part of the lymph but the purest, and that only but by slow degrees.

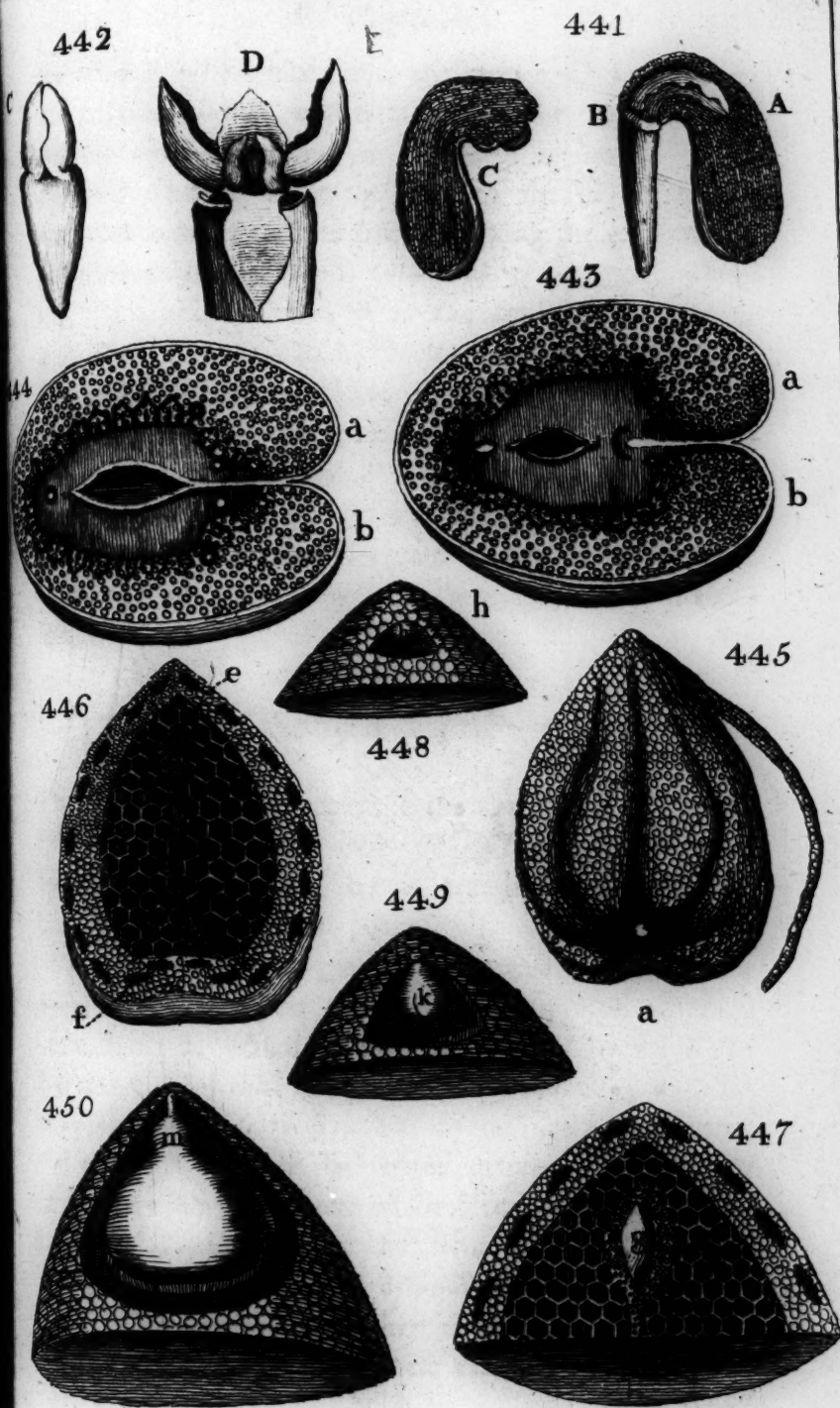
If with a steady hand this membrane be pulled very gently upwards, it will draw a small transparent string after it to the bottom of the middle membrane: this said string, though for the greater part parenchymous, is nevertheless strengthened with some lignous fibres, which seem to be a portion of those that are inosculated at the bottom of the outer membrane, and thence produced through the middlemost under the channel which joins the two oval cavities, till at last they break forth into the upper cavity, where they form this inner membrane, which is originally as entire as the middlemost; but as it increases, becomes a little hollow near the cone, and the aforesaid lignous fibres fetching their compass from the base, shoot forth into the cone, and make a very small node therein, for the first essay towards the generation of the seed, as at *h*, fig. 448. which are spun out to the ut-

most degree of fineness for that purpose. In this figure the inmost cover is laid open to shew the seed itself.

When this node is grown to about the size of the fifth part of a cheese-mite, it begins to be divided by a little indenture towards the top, as at *k*, fig. 449. which gradually grows deeper till the node is distinguished into lobes or thick leaves; and as these increase, their base is contracted into the radicle, or that part of the seed which becomes the root; at this time the seed is so extremely small, that the lobes cannot be separated; but it is probable, that as soon as the radicle is finished, the next step is the pushing forth another node between the lobes, in order to the formation of the bud, and so the perfection of the seed.

This being done, or doing, the stalk of the seed is more and more contracted at bottom, and hangs at the inner membrane only by an extremely small and short ligament *m*, fig. 450. which at last breaks; and then the seed, as fruits when ripe, falls off and lies loose in the inner membrane, which gradually shrinks up and becomes more hollow to make more room for the farther growth of the seed.

In Malpighi's life was a debate between him and Signior Triumphetti, provost of the physick garden at Rome, whether the whole plant be actually contained in the seed? the affirmative is maintained by Malpighi with cogent arguments; among which this is one, that in a kidney bean, 'ere sown, the eye, assisted with a microscope, easily discovers leaves, a bud, and even the knots or implantation of the leaves on the stem. The stem itself is very conspicuous, and plainly consists of woody fibres, and a series of little utricles. Whereas Signior Triumphetti had objected, that by poverty, transplantation, &c. several plants degenerate into others, parti-



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particularly wheat into tares, and tares again into wheat. In answer to this, which is one of the strongest objections against that opinion, Malpighi replies, that he is not fully satisfied as to the truth of the objection; for that both himself and his friends making the experiment, no metamorphosis of the wheat succeeded: but granting the metamorphosis, it is the soil, or the air, or the culture that is in fault. Now, therefore, from a morbid, and monstrous condition of nature, there is no inferring her genuine and permanent state.

That experiment related in the following section, of the orange kernel, which Mr. Leeuwenhoek made to germinate in his pocket, is a plain demonstration, that the plant, and all that belongs to it, was actually in the seed itself.

Of the seed of oranges.

THE process of nature in the vegetation of plants, is very accurately deliver'd by Mr. Leeuwenhoek, to the effect following, by an orange kernel which he made to germinate in his pocket, viz.

The kernels of oranges being divested of their outer membrane, will appear as fig. 451. on one side of which lies a string *a*, which causes a little protuberance in the first skin; from this string, not only the seed, but also the plant within it, receive their increase and nourishment, and to which through the second membrane, it extends its small vessels to the seat of the plant. Mr. Leeuwenhoek was of opinion, that this string does actually comprehend in itself, as many distinct vessels as are to be found in the orange-tree when arrived at its full maturity ^b. For, says he, if all these vessels were not in the

Q 4

young

^b Phil. Transf. No. 287.

young plant, whilst it lies involved in the kernel's matrix, whence could they afterwards proceed? Fig. 452. represents part of the same string, cut a-crofs, and greatly magnified, which at K L M N, has abundance of exceeding small vessels, but very difficult to be perceived. About I H N M, they grow larger, and consequently are more visible. B, fig. 453. represents a seed divested of its membranes, which seemed to have but one plant within it, though often there are two, and sometimes three distinct seeds with their plants contain'd under the membrane of an orange kernel; these seeds, with their inclosed plants, are easily divided into two lobes; which are framed by nature to nourish the tender plant within, till it is able to stand alone, and draw its subsistence from the earth about it; having split the seed into two parts, they are represented by C and D, fig. 453. in the first, is part of the plant, which would have become a tree, and is no bigger than a grain of sand to the naked eye. The counterpart of the said kernel is represented at D, with the concave, in which part of the plant lay. Fig. 454. represents the last mention'd plant, as it appear'd in the microscope, whereof Q L M is partly that which nature intends for the body and root of the tree; M N O P Q the leaves with which the young plant is already provided, N O P that part of the leaves which is somewhat protuberant, by reason of the small inclosed leaves M N, and P Q shew the two sides of the plant torn off from the kernel, to which it was united, and from which it received its nourishment. Fig. 455. S T V, shews the same plant a little turned about before the microscope, in order to represent the two largest leaves, between which, according to all appearance, a great many small ones are shut up. If the leaves be cut a-crofs, some of the included ones may sometimes be discerned, and on cutting that
part

part of the plant which is to be the body and root of the tree, that which was designed for the pith, and even the wood itself may be discover'd.

Fig. 456. shews the root when the plant vegetates, T V and W X the two halves of the kernel, and Y that part which is to become the body of the tree.

Fig. 457. represents the young plant of twelve days growth, whereof A C D shews the root, and F G that part which is to be the tree, D E the seed or kernel, which being surrounded with its membrane, which was taken off the better to expose those parts to view, that serve for the nourishment not only of the root, but of the upper parts of the plant likewise, as also the short string D. Thus we may see how small a particle, that is no bigger than a grain of sand, * as the plant was at first, is increased in bulk ! and all this is brought about by heat and moisture, it being rais'd to this degree of perfection in some sand first moistened, and then inclosed together with the seed, in a glass tube, wore all day in the pocket, close to the body, and at night, placed within a large tin bottle, filled with hot water, which is a plain demonstration that the plant, and all that belonged to it, was actually in the seed ; that is to say, not only the young plant, its body, root, and fruit, but even its seed also, to perpetuate the species ; as hath been before observed.

Mr. Leeuwenhoek comparing the animalcula in semine masculino, and these plants, computes them to be one million times smaller than a plant in an orange-kernel ; and though we cannot make our observations of the growth and increase of the said animalcula from time to time in their mother's matrix ; yet we may certainly conclude, that the laws which the wise creator of all things hath prescribed to himself, in the production both
of

of animate and inanimate creatures, are homogeneous and uniform; and that as the earth is the common matrix of plants, so is the fallopian tube in most of those animals that are formed *ex semine masculino*; for as these receive their nourishment, and increase by a string, till they are brought into the world; so are all seeds (at least as far as we know) supported and nourished by a like string; and the seeds thrown into the ground, do again, by the same string, whereby they received their increase, convey nourishment to the seed or kernel.

Of the seeds of venus looking-glass, or corn violets.

FIG 458. represents one of the seeds of corn-violets; the seed is very small, black, and shining, and to the naked eye looks almost like a very small flea, but through the microscope appears to be covered with a tough, thick, and bright, reflecting skin, very irregularly shrunk, and pitted, that it is almost impossible to find out two of them wrinkled alike, so great a variety there is even in this little seed.

Of the seeds of thyme.

THESE little seeds, although they differ somewhat in figure and bulk, yet when looked at through the microscope, all of them exactly resemble a dried lemon, one of which is represented at fig. 459. some of them are a little rounder, and of the shape of an orange. They have each of them a conspicuous part, by which they are joined to their little stalks; they are a little creased or wrinkled, as is expressed in the figure.

Of

Of the seeds of poppy.

POppy seeds, one of which is represented in fig. 460. deserve to be taken notice of among the other microscopic seeds of vegetables; both for their smallness, multiplicity, and prettiness, and also for their admirable soporific quality, although they grow in a very large case, yet are they so small, as not to exceed the bulk of a very small nitt, being not above one thirty-second part of an inch in diameter; whereas the seed case oftentimes exceeds two inches, and is therefore capable of containing near two hundred thousand of them. They are of a brownish coloured red, curiously honey-combed all over with a pretty variety of net-work, or a small kind of embossment of very orderly raised ridges.

Of purslane seed, &c.

THE seeds of purslane seems of very notable shapes, and appear through the microscope like porcelane shells, as at fig. 461. It is coyled round in the manner of a spiral; at the greater end, which represents the mouth or orifice of the shell, is a white, skinny, transparent substance B, which seems to be the place where the stem was joined. Its whole surface is covered with little prominencies, orderly ranged in spiral rows; one of these being cut asunder with a sharp penknife, discovered the shell to be of a brownish red, but somewhat transparent, and manifested the inside to be filled with a whitish green pulp, the bed wherein the seminal principle lies enveloped.

Fig.

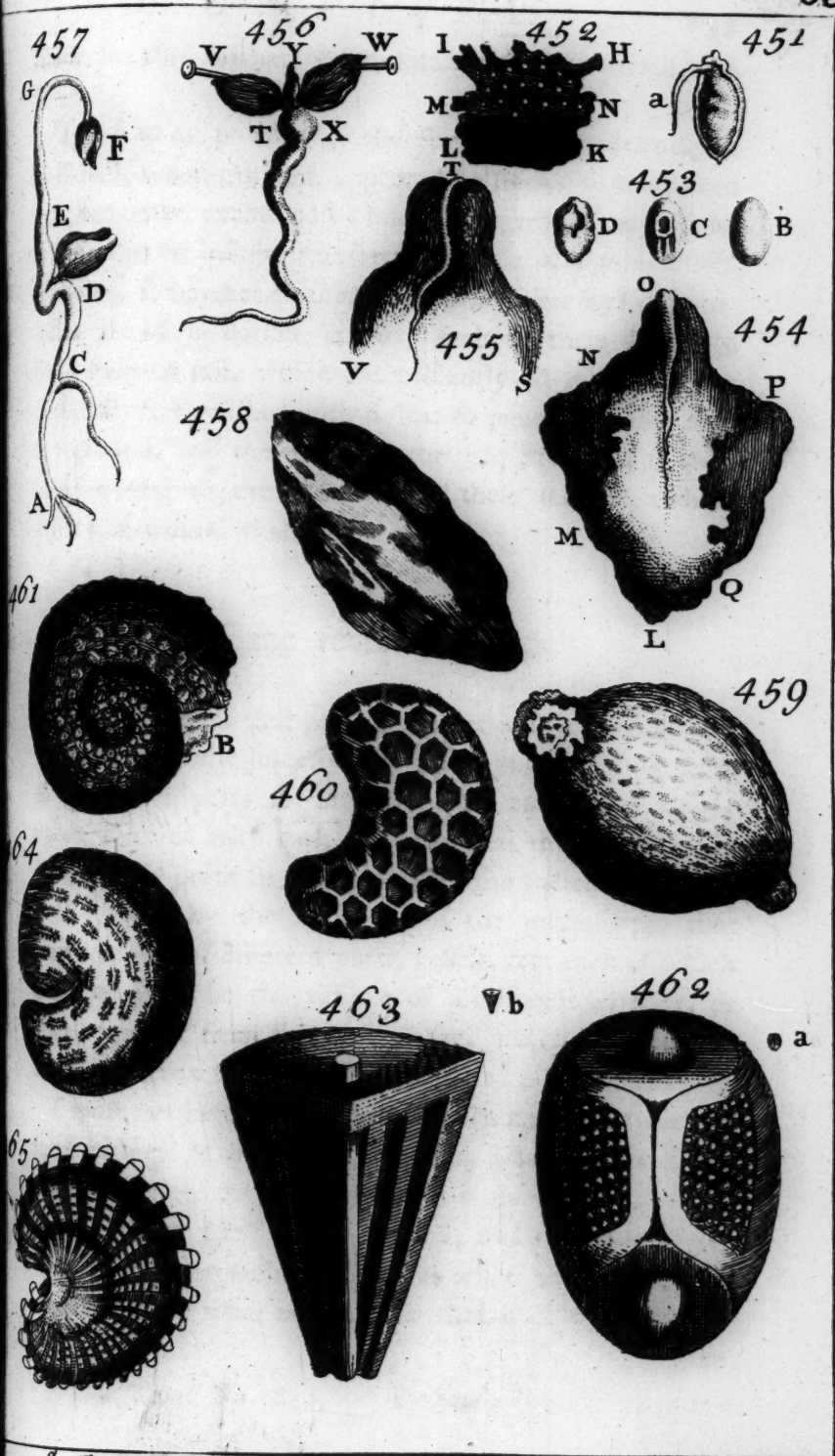
Fig. 465. represents the seed of ben; it is something like a kidney, but hath its circumference raised up into double ridges, towards which several small ridges do in some sort radiate from one center.

Fig. 464. represents the seed of chickweed, this also is partly like a kidney, and partly like a retort, being rough cast with small pieces, as if they were insects with little feet.

Fig. 463. represents the seed of bellis tanaceti folio. It hath two triangular sides, and the third conical; the two first have several ridges running to the base, the head triangular with one side convex, the other two streight, with a little pinnacle in the center.

Fig. 462. represents the seed of wartworth, or sun spurge, it is of a very complex figure, its belly consisting of two planiconic sides, and back sphericonic. The base and head are both flat, in the middle of the former is a peg, by which the seed is fastened, and of the latter a pointed knob. The belly-sides is hollowed, so as to make a flat rim of equal breadth; and the hollows filled up with bladders, like those of the parenchymous parts of a plant.

There are multitudes of other seeds, which imitate the forms of divers sorts of shells; as seed of scurvy-grass, a kind of purcelane shell; others represent several sorts of larger fruits; sweet and pot marjoram represent olives, carrot-seeds are like a cleft of a cocoa nut husk. Others are like artificial things, as succory seeds are like a quiver of arrows, the seeds of aramanthus are somewhat like an eye, the skin of the black and shrivelled seeds of onion, are all over knobbed like a seal skin, and sorrel has a black shining three-square seed. It is almost endless to reckon up the several shapes of seeds, they being so many and so various in their forms. I shall therefore leave them





them to the further examination of the curious observer.

The seed or powder of the fungus purverulentus, or puff-ball, when crushed, appears like sinoak to the naked eye, but when examined by one of the greatest magnifiers, is found to be infinite numbers of little orange coloured globules, somewhat transparent; in another sort the globules are of a darker colour, each of them having a little stalk or tail, which are evidently so many minute puff-balls ^d, furnished with stalks, to penetrate easily into the ground, and the mischiefs they do the eyes, is probably owing to the sharpness of these stalks ^e, which prick and wound that tender organ.

Of the roots of plants.

THE root is that part of a plant which immediately imbibes the juices of the earth, and transmits them to the other parts for nutrition. It consists of woody fibres, covered with bark, more or less thick, and arises from a little point in the seed called the radicle.

We learn by the assistance of the microscope, that plants consist of different parts, vessels, &c. each of which is supposed to be the vehicle of a different humour, or juice, secreted from the mass of sap, which is considered as the common fund of them all.

I must not here omit a curious phenomenon in the natural history of plants, and that is, when the radicle in sowing happens to light lowest, it is no wonder the root should spread itself under ground, and the stem of the plant rise up perpendicularly: but when the radicle falls uppermost, by what means it is that it changes its position,

^d Phil. Trans. No. 284.

^e Derham's Phys. Theo. p. 418.

tion, to favour the ascent of the stem, is one of the wonders of vegetation.

M. Dodart first observed this perpendicularity of plants, and published it in an express essay of the affectation of perpendicularity, observable in the stems or stalks of plants, &c.

The matter of fact is, that though almost all plants rise a little crooked; yet the stems shoot up perpendicularly, and the roots sink down perpendicularly; even such as by the declivity of the soil come out inclined, or are diverted out of the perpendicular by any violent means, again redress or strengthen themselves, and recover their perpendicularity, by making a second or contrary bend, or elbow, without rectifying the first.

A common eye looks on this affectation without any surprize; but a man, who knows what a plant is, and how formed, finds it a subject of astonishment.

It has been before shewn, that each seed contains a little plant, already formed, needing nothing but to be unfolded; the little plant has its little root and pulp, which is generally separable into two lobes, and is the foundation of the first food the plantule draws by its root, when it begins to germinate.

If a seed in the earth be so disposed, as that the root of the little plant be turned downwards, and stem upwards, and even perpendicularly upwards; it is easy to conceive, that the little plant coming to unfold itself, its stalk and root need only follow the direction they have to grow perpendicularly. But,

It is very well known, the seeds of all plants, whether sown of themselves, or by the help of man, fall into the ground at random; and among an infinite number of situations, with respect to the stalk of their plant, the perpendicular direction upwards is but one.

It

It is therefore necessary that the stalk redress or rectify itself in all the other situations, in order to find its way out of the ground : but what force is it that effects this change, which is certainly a violent action ? Is it, that the stalk finding a less load of earth above it, goes naturally that way where it finds the least obstacle ? were it so, the little root when it happens to be uppermost, must for the same reason follow the same direction, and mount on high.

Therefore M. Dodart supposes the fibres of the stalks are of such a nature, as to contract and shorten by the sun's heat, and lengthen out by the moisture of the earth ; and on the contrary, that the fibres of the roots contract by the moisture of the earth, and lengthen by the heat of the sun.

Then when the root of the plantule is uppermost, the fibres which compose one of the branches of the root, are not equally exposed to the moisture of the earth ; the lower part is more exposed to the upper, which must therefore contract the most ; this contraction is again promoted by the lengthening of the upper, whereon the sun acts with the greatest force ; consequently this branch of the root must recoil towards the earth, and insinuating through the pores thereof, get under the bulb, &c.

By inverting this reasoning, it will appear, how the stalk comes to get uppermost.

In a word, we may imagine, that the earth attracts the root to itself, and that the sun contributes to its descent ; and, on the contrary, that the sun attracts the stem, and the earth in some measure sends it towards the same. Again,

M. de la Hire imagines, that the root draws a coarser and heavier juice, and the stem and its branches a more volatile one ; which difference of juices, supposes larger pores

pores in the roots than in the stalks; therefore in the plantule we may conceive a point of separation; such, that all one side of the root shall be unfolded by the grosser juices, and all the other side by the more subtile ones.

If now the plantule be inverted when its parts begin to unfold, the juices which enter the root being coarsest, when they have enlarged the pores to admit juices of a determinate weight, those juices pressing the root more and more, will drive it downwards, and this the more as the root is more extended or enlarged; for the point of separation, being conceived as the fix'd point of a lever, they will act by the longer arm. At the same time the volatile juices having penetrated the stalk, will tend to give a direction from below upwards, and by reason of the lever, will give it more and more every day till it be perfectly erect.

Mr. Astruc accounts for perpendicularity of the stems, and their redressing themselves on these two principles.

First, that the nutritious juice arises from the circumference of the plant, and terminates in the pith. Second, that fluids contain'd in tubes, either parallel or oblique to the horizon, gravitate on the lower part of the tubes, and not at all on the upper.

Whence it easily follows, that in a plant posited either obliquely or parallel to the horizon, the nutritious juice will act more on the lower part of the canals than on the upper; and by this means insinuate more into the canals communicating therewith, and be collected more copiously therein; thus the parts on the lower side will receive more accretion, and be more nourished than those on the upper; the consequences whereof must be, that the extremity of the plant will be obliged to bend upwards.

The

The same principle brings the seed into its due situation at first; in a bean planted upside down, the plume and radicle are easily perceived with the naked eye, to shoot at first directly for about an inch; but thenceforward they begin to bend, the one downwards, and the other upwards, as in the example of the orange seed, fig. 457; the like is seen in a heap of barley to be made malt, in a quantity of acorns laid to sprout in a moist place, &c. each grain of barley in the first case, and each acorn in the second, hath a different situation, and yet all the sprouts tend directly upwards, and the roots downwards, and the curvity or bend they make, is greater or less as their situation approaches more or less to the direction wherein no curviture at all would be necessary. Now two such opposite motions cannot arise without supposing some considerable difference between the two parts; the only one we know of, is, that the plume is fed by a juice, imported to it by tubes parallel to its sides; whereas the radicle imbibes its nourishment at all the pores in its surface. As oft therefore as the plume is either parallel or inclined to the horizon, the nutritious juice, feeding the lower parts more than the upper, will determine its extremes to turn upwards, for the reason already assigned. On the contrary, when the radicle is in the like situation, the nutritious juice penetrating more copiously through the upper part than the under, there will be a greater accretion of the former than the latter; and consequently the radicle will be bent downwards; and this mutual curvity of the plume and radicle must continue, till such time as their sides are nourished alike, which cannot be till they are perpendicular ^f.

Roots are generally distinguished by their figures, some being entire, as liquorice; parted, as saint johnwort; some

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parted

^f Men. d. l. Acad. Roy. des Sciences, No. 1708.

parted at bottom, as most roots; others at top, as dandelion, &c. some parted and ramified, as comfrey; others having divers strings issuing from one head, as crowfoot; some strait as raddish, crooked as bistort, smooth as bugloss, stringy all round as columbine; some thick as rhubarb, slender as the vine, long as fennel, short as turnep, &c. &c.

The motions of roots are sometimes perpendicular, as parsnip, level as hops, ammi, cinquefoil, &c.

There is a kind of wreathing or twisting in the vessels of some when the bark is stripped off, in carduus, sonchus, &c. in which may be sometimes seen two or three circumvolutions.

But the most remarkable of all roots are such as are annually renewed or repaired out of the trunk or stalk itself, as arum, rape-crowfoot, valerian, brownwort, bearsfoot, tansy, lychnis, sapier, primrose, ammi, avens, wood-forrel, iris, and others; that is to say, the basis of the stalk continually and by insensible degrees, descending below the surface of the earth, and hiding itself therein, is both in nature, place, and office, changed into a root. So in brownwort the basis of the stalk sinking down by degrees till it lies under ground, becomes the upper part of the root; and continuing still to sink, the next year becomes the lower part, and the next after that rots away, & a new addition being yearly made out of the stalk, as the older parts annually rot away.

In a dissection of the root we shall first find the skin, next the cortical, which when thin is commonly called the bark; next within this are the woody fibres, which together with all its parts, are visible in a circle; its pores being nothing near so numerous as that of the cortical, but in some more open than in others, as may be seen on cutting

cutting a very thin transverse slice of the branch of a tree, and holding it against the light, or placing it before the microscope. In currant and gooseberry-trees it is less conspicuous than in oak or plumbs, in damsons it is more, and in elder and vines more; the cortical body doth not only surround the wood, but is as it were wedged into it in many places, and is even inserted therein as far as the pith, and appears in a transverse section of a root-like lines drawn from the center to the circumference.

Fig. 466. represents a transverse slice of the root of asparagus, and fig. 467. exhibits a microscopic picture of a piece thereof cut out at a b, in which A B shews the skin: A B C D the bark, or all that part analogous to it: C D E F the lymphæducts on the inner edge of the bark: E F G H the wood in which the black spots shew the air vessels: G H I the pith.

Fig. 468. is a transverse slice of the root of mallows. Fig. 469. represents a piece thereof, which was cut out at c d, as it appeared before the microscope; in which A B C D shews the skin: C D E F the bark, or all that part of the root which answers to it, in which the round spots are the muciducts: E F G H the common lymphæducts: G H I K the pithy part of the root: I K L more lymphæducts, in both which the black holes are the air vessels.

Fig. 470. represents a slice of a vine root cut transversly, out of which at e f was cut a small piece, which when placed before the microscope appeared as represented by fig. 471. wherein A B shews the skin: A B C D the bark: L S parcels of sap vessels: L I parcels of wood in which the darker shaded circles great and small are the air vessels: E F parenchymous insertions between the parcels of wood: G G others within them.

At fig. 472. is seen a transverse slice of a horse-raddish root, and at a b the place from whence a gore was cut, which is represented as it appeared in the microscope by fig. 473. whereof A B is the skin: A B C D the bark: C D E F G H I the sap vessels in form of a glory: C D K L the wood in which the darker circles are the air vessels: K L M N a ring of more sap vessels: M N O the pith.

Fig. 474. exhibits a transverse section of buglose root, from which at c d was taken a small piece, that when magnified appeared as fig. 475. in which A B is the skin: A B C D the bark: A B E F the bladders in the outer part of the bark; they are figured somewhat oblong, and are ranged in circles: E F C D the inner part of the bark in which the bladders are ranged in curved arches: C D G H a ring of sap vessels: I I a parenchymous insertion, of which there are several in the whole section: L K K L the wood in which the dark spots are the air vessels: K K M the pith.

Of the skin of roots.

THE outer parts of all roots is the skin, which in skerrits is white, yellow in dock, red in potatoes, brown in lovage, black in bugloss, &c. their surface is sometimes smooth, as in horse-raddish, rough, as in scorzonera. The skins of the several shells of a tulip-root fresh taken up, appear to be perforated with a number of small holes. This skin is very thin in parsnip, thicker in bugloss, very thick in iris, opake in some as the thistle, and transparent in others, as the madder.

Every root hath two kinds of skin, one of the same age with the other parts, and the other succeeding in the place of the former; as in dandelion, the old skin seems to

to be that part which composed the cortical body the year before, which by the generation of a new ring next the wood, is now thrust outward, and shrunk up into a skin as at A B ; in an horse-raddish root, fig. 473. or at A B in a bugloss root, fig. 475. as far as the bladders in the former, and vessels in the latter, are radicated ; the cortical body seems to shrivel up into a new skin, as the old ones fall off, and probably the whole body of the perpendicular roots, except the woody fibre in the center, becomes the second skin, as in asparagus, fig. 467.

This skin is made up of two kinds of bodies, one parenchymous, generally composed of exceeding small cells or bladders, which are plainly visible, if viewed through a microscope, and appear as in fig. 467. which represents a transverse piece of the root of asparagus, &c.

The other part of this skin is composed of tubular wood-vessels, intermix'd with the bladders before-mention'd.

If a root be cut transversely, and laid by for some time, all the parts where there are no vessels will shrink below the surface of the cut end ; but the vessels will all retain the same length, at which time they may be examined by the microscope.

Of the bark of roots.

THE bark is situate just within the skin, in some roots it is yellow, as in dock, red in bistort, but in most white, in some it is very thin, and in others it makes the greatest part of the root, the thinnest and thickest being all analogous.

It is exceeding porous both in length and breadth, as appears from its shrinking up equally both ways, and dilating to its former size on being soaked in water. All

this is apparent to the naked eye; but the microscope confirms the truth thereof, by shewing that these pores are an infinite number of little cells or bladders, sometimes running in ranks both the length and cross-ways of the root, as at ABCD in bugloss. Fig. 475. it may be seen both in a transverse and upright section, and always best after the pieces so cut have lain by some time to dry.

This parenchymous part is of an uniform texture in many roots, and diversified in as many others; the bladders, though very regular, yet differ in shape, size and situation; in some places like white rays, streaming from the inner edge thereof outwards to the circumference of the bark, as is apparent in a transverse section of lovage, melilot, parsnip, &c. continuing in direct lines the whole length of the root.

The bark, as before observed, is intermixed with a few lignous vessels, which are apparent in most roots in the resemblance of threads. These tubular threads do not run in direct lines, but are frequently braced together in the form of network, as is apparent if the bark be stripped off, and a piece of it examined by the microscope.

In parsnips these vessels yield a thin lymph. It is certain that this clear sap ascends only in these vessels, because no liquor will do the like from any parenchymous part; sometimes they yield a thick mucilaginous lymph as comfrey; oftentimes these succiferous vessels yield a milky or white sap, and sometimes yellow, as in sonchus, and most cichoraceous plants; in angelica, and most umbelliferous; in burdock and divers thistles; in scorzonera, common bells, and many other plants, not commonly taken notice of to be milky. These milky saps, although of different colours, thickness, and other qualities, agree in being more oily than any of the lymphous saps; for the mixture of the oily parts, with some other limpid liquor,

quor, causes them to be of a milky ^h, or other opaque colour. In the same manner as common oil, and a strong liquament of tartar, shook in a bottle, become white.

Sometimes the oil will separate, as is observable on cutting a fennel root transversely, after it hath lain some days out of the ground. The same vessels, which before yielded milk, will now yield oil.

All gums and balsams are likewise the contents of these vessels, for these and milks are nearly a-kin. The milk of fennel standing some time, turns to a clear balsam, of scorzonera; dandelion, and others, to a gum. In the dried root of angelica, when split, the milk ⁱ is seen in clods, in the continuation of these vessels, condensed into an hard shining rosin. The root helenium cut transversely, presently yields a balsam of a citron colour, so called because it will not dissolve in water. The root of common wormwood yields a true balsam, with all the defining properties of a terebinth; the roots of trachelium and enula, yield both a lymph and a citron balsam; and wormwood both a lymph and a terebinth ^k at the same time. It is doubtful whether all roots have lymphæducts, but probably they have, and for the most part standing in a ring, at the inner verge of the bark.

The situation of these vessels are very curious, if viewed in a transverse section of the root; sometimes they only form a ring at the inner edge of the bark, as at E F, in asparagus, fig. 467. in which position they are in most, if not all roots; in some they stand in rays, as borage, or peripherial, as in celandine. These vascular rays are extended in some towards the circumference of the bark, about half way, as between C D E F, in bugloss, fig. 475. in all docks and sorrels, about three fourths of the thickness of the bark towards the circumference, several

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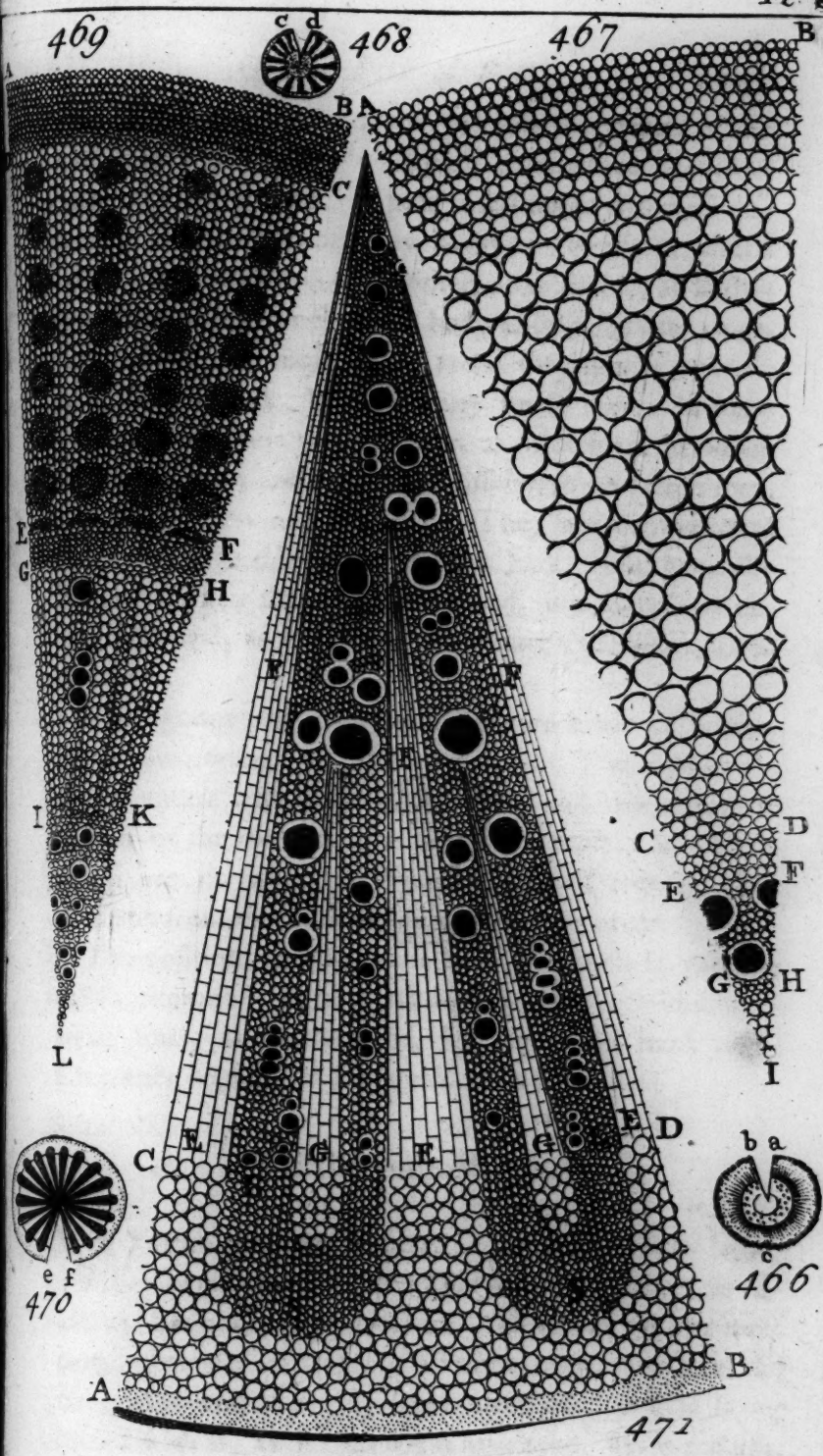
of

^h Grew. An. Plant. p. 67. ⁱ Ibid p. 67. ^k Ibid. p. 68.

Of them are also arched thereabout. In all, or many trefoils, and of the leguminous kind, only one third of the bark. In the umbelliferous, they are situate between the diametrical portions of the parenchyma. In the microscope they all of them appear to be real circles; and in a transverse section, when the milk has been licked off with the tongue, till no more will rise. They may also be soaked in water, after which the position of the milk vessels will be visible; in some roots they run more parallel and keep asunder, as in monks-hood, and join towards the circumference of the bark, in eryngo. They terminate more circular, in briony angular, or in the form of a glory, as will appear also on viewing an horse-raddish root, C D E F G H I, fig. 473. in the microscope. In some almost entire circles, as in dandelion; in others composed of short chords; in some these specks are so exceeding small, that to the naked eye they seem continued rings, but when viewed in the microscope, are distinct vessels, as in marsh-mallows, and liquorice. In marsh-mallows the lymphæducts appear in rays, and the lacteals in rings, fig. 469. In dandelion they appear to the naked eye like numerous rings, but when viewed through the microscope, are found to consist of very many small rays, streaming from the inner verge of the bark, a-cross three or four of the smaller rings.

Of the wood of roots.

THAT portion of the root, which is contiguous to, and within the bark; in trees, and shrubby plants, is the wood, which consists of the parenchyma and lignous substance. The first of which is of the same nature with that of the bark. The position of its several parts are mostly diametrical, running between the lignous parts,





parts, from the circumference towards the center of the root, and all together constitute that which is before called the insertment. These insertments are most observable in the roots of many herbs, as comfrey, which exhibits a good notion of all other, as well trees as herbs; sometimes this parenchymous body is disposed into rings, as in fennel. In most woody roots, they stream between the pith and bark, like so many small rays. In some roots they continue to the center, as columbine, in others not, as parsnip; and sometimes different in the same root, as E F in the vine, fig. 471. They are composed of many small bladders, as in the bark, but generally smaller. Their shape usually round, but sometimes oblong and oval, as in borage, or oblong and square, as in the vine.

The lignous part also consists of two kinds of bodies, succiferous, or lignous, and air vessels. The lignous are of the nature with those of the bark, and in a transverse section of the root, emit a liquor as those do. These vessels are no where interwove or braced together, but continue from one end of the root to the other.

The position of both these kind of vessels is various, the succiferous or lignous are sometimes situate in diametrical lines, as in the vine, fig. 471. and most trees, sometimes opposite to the areal, as in beet, &c.

Of the pith of roots.

Within the woody part, is the pith, which is not common to all roots, for some have none, as nicotian, stramonium, and others. The pith, for the most part, especially in trees, is a simple body, yet like the bark it is compounded, some succiferous vessels being mixed with it, as in jerusalem artichoke, horse-raddish, &c.

&c. many roots that have no pith at their lower part, have one at the top, as columbine, lovage, &c. Their contexture by the microscope, appears to be of the same general kind in all plants, both in the parenchyma of the bark, in the insertment or diametrical portions, and in the pith, all being composed of bladders, which are of very different sizes, seldom less than those of the bark, as in asparagus, fig. 467. but generally much bigger, as in horse-raddish, fig. 473. their position seldom varies, but is uniform in a transverse section of all parts of the root piled up evenly one over another. In an upright section they seem to run in direct trains, length-ways; they are for the most part orbicular, though in the larger roots somewhat angular. On observing these bladders with the microscope, their sides will be found to consist of several ranks of exceeding small fibres, lying for the most part evenly one over another, from the bottom to the top of every bladder, and running a-cross also from one bladder to another. If the pith be cut with a sharp razor, or penknife, and so applied to the microscope, they will be seen distinctly.

All plants exhibit this spectacle, but those best with the largest bladders; nor the same pith so well in any other condition, as when dry; because then the sap being voided, the spaces between the fibres, and the fibres themselves are more distinctly seen. Yet it must not be dried after cutting, because its several parts will thereupon coincide and become deformed, but to be chosen while the plant is growing, at which time it may be often found dry and not deformed; as in the trunks of common thistle, Jerusalem artichoke, &c. cut off the white bottoms of the bladders of a bullrush transversely, and they will appear like a curious piece of needle-work. The whole body
of

of a root therefore consists of vessels and fibres, and probably these fibres themselves are tubular.

If you take the roots of vine, fennel, dandelion, plumb-tree, elder, willow, &c. and lay them for sometime to dry, then cut off a thin slice of each transversly, and place it before the microscope, by pinching one edge thereof between the nippers, the light will then be trajected through the perforations of all the vessels both great and small, they are scarce ever visible in the fresh slices of these roots.

A clear and elegant sight of the fibres which compose the air vessels, may be obtained by splitting a vine root, or a piece of oak, and may be seen in the side of the greater air vessels, in the resemblance of needle-work; the spiration of the fibres may be better observed in the trunk than in the root, and best in young plants, but not so well by cutting as splitting, or by tearing off some small piece, through which they run; their confirmation being by this means not spoiled.

But in the leaves or tender stalks of all such plants as shew upon breaking a kind of down or wool, they may be seen drawn out, and that sometimes to the naked eye. This wool being nothing else but a certain number of fibres drawn out of their spiral position, appearing more or less in the leaves and other parts of most plants, as in the vine, scabious, &c. in the scales of a squil they are so easily separable, as to shew the plate or zone into which the air vessels are usually resolved, which is not one single piece, but made up of several round fibres, running parallel, and knit together by other smaller ones transversly in the form of a zone.

Of the trunks of trees.

THE trunk comes next under consideration, which consists of the bark, the wood, the insertions or veins, and the pith.

The cross shootings of the wood in trunks of several years growth appear in rings, so that we may judge by the number of rings of how many years¹ growth the tree is; in each of these rings is one circle of large open pipes, but the fewer of these the stronger the timber.

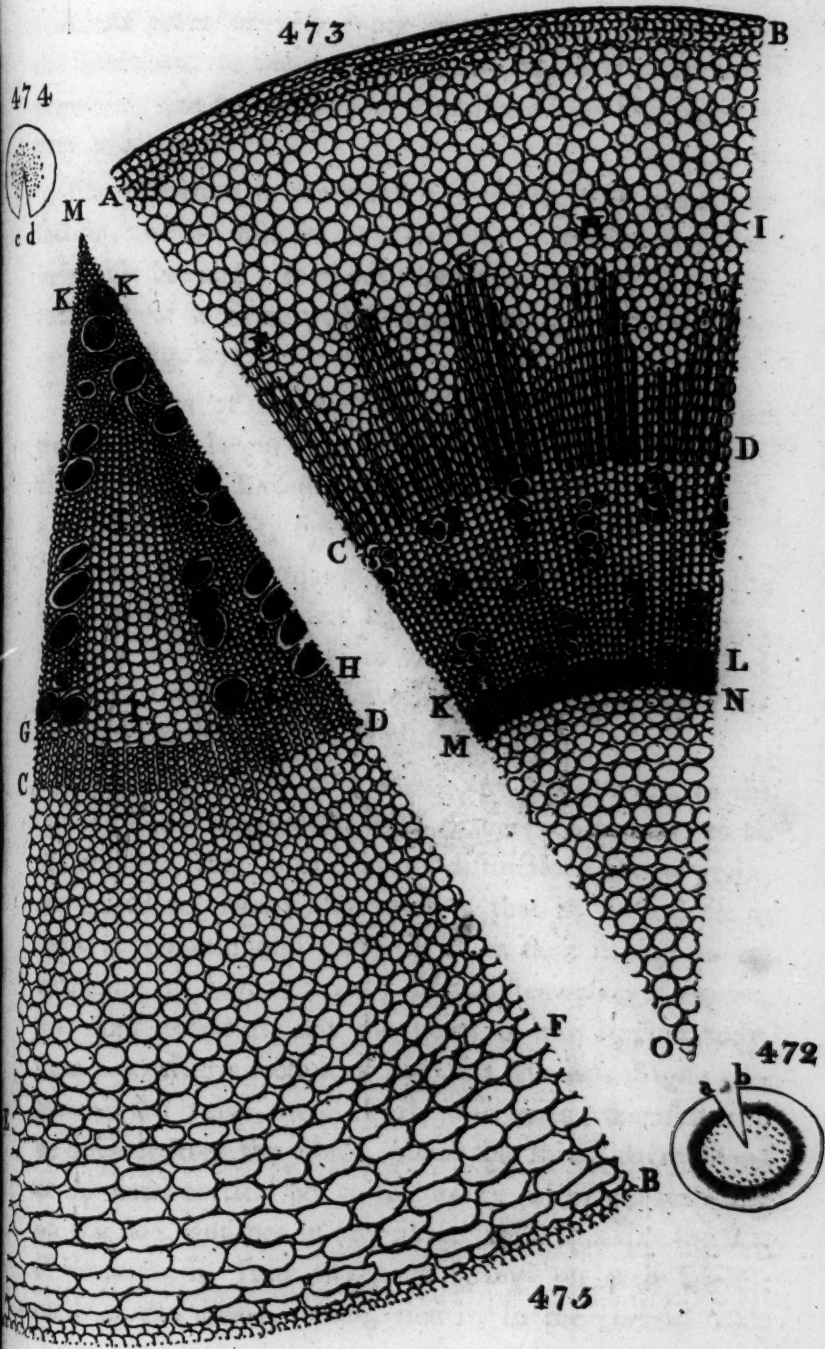
The pores of the wood in well-grown timber are very conspicuous both in an upright and transverse section thereof.

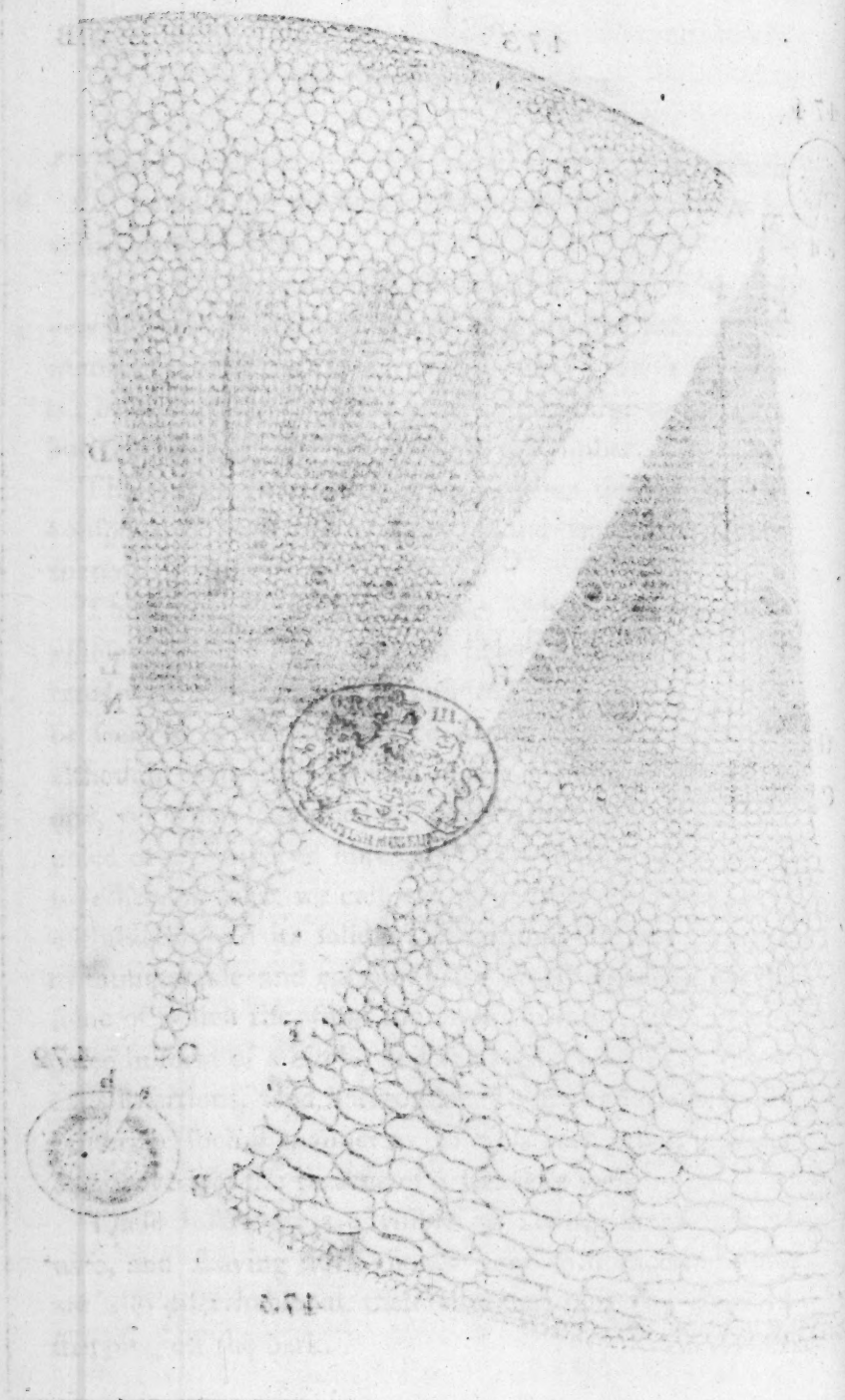
The lignous body in the trunks of herbs are extremely visible in the microscope, each fibre thereof being perforated with thirty, fifty, an hundred, &c. pores, as may be seen in a magnified piece of burdock, fig. 477. and although each fibre appears to the naked eye to be but one, yet when magnified we plainly find them to be composed of a number of fibres, or rather hollow tubes joined together, so what we call the woody part of a tree, notwithstanding all its solidity, is nothing else but a cluster of innumerable and extraordinary small vascular fibres; some of which rise from the root upwards, and are disposed in form of a circle, and the others which Dr. Grew calls insertions, tend horizontally from the surface to the center, in such a manner as to cross each other, and are interwove like the threads of a weaver's web.

These insertions are visible on sawing trees lengthwise, and shaving from thence very thin slices. They are also discernable at their entrance into the wood on stripping off the bark.

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¹ Phil. Transf. No. 213,





As the pores or vessels are greater or less, so are also the insertions, to the naked eye, the largest only are discernable ; but by the help of the microscope they appear very numerous.

The insertions in the trunk are visible in a transverse section, and are disposed in even lines or rows throughout its whole breadth ; they are represented as they appear in the root of a vine, when viewed through a microscope, by E F, fig. 471.

The pores of the pith are mostly observable in the trunk, being larger than in the root ; and through a microscope appear like so many bubbles or bladders, as in a piece of burdock, fig. 477.

In the piths of many roots and plants, some of the larger pores or bladders have smaller ones within them, some of which are divided with cross membranes, and between their several sides other smaller bladders are inserted, in orderly ranks length-wise.

What Dr. Grew calls fibres and insertments, or the lignous body interwoven with that which he takes to be the cortical, that is the several distinctions of the grain, are called by Mr. Lister veins ^m, that is, such ducts as seem to contain and carry in them their noblest juices, analagous to human veins. Mr. Lister makes it appear, that these vessels are not the pores of the lignous body, from a transverse section of *angelica sylvestris magna vulgarior* ; the veins there clearly discovering themselves to be distinct from the fibres, observable in the parenchyma of the same cortical body, the milky juices always rising on the side, and not in any fibre. Also in a like incision of burdock, in June the juice springs on each side the radii of the woody circle, that is, in the cortical body
and

^m Phil. Transf. No. 79.

and pith only; again where there is no pith none of this juice is observed.

In a transverse cut of a leaf it is observable, 1. That these veins accompany the ribs and nerves. 2. That the middle fibre or nerve seems to yield one big drop of a milky juice springing as it were from one vein, yet by the microscope it is plain there are many veins, to the making up of that drop. 3. That if a fibre or nerve be carefully taken out of the leaf, the veins will appear therein like so many pipes running along the nerve, and yet these numerous veins are all of an equal bigness.

It is observable in the motion of these juices, that the milky juice always moves and springs briskly upon the opening of a vein^a, the limpid sap only at certain seasons.

Dr. Grew assigns the offices of the several vessels, viz. those placed on the inner verge of the bark, he calls lymphæducts, and supposes them destined for the conveyance of the most watery liquor; these Mr. Bradley calls the new forming vessels, which are annually produced, and help to increase the bulk of the tree.

Those in the middle of the bark Dr. Grew calls lactiferous or resiniferous vessels: their use, according to Bradley, is to return the superfluous sap: these vessels, Grew observes, are the principal viscera of plants; and adds, that as the viscera of animals are but vessels conglomerated; so the vessels of a plant are viscera drawn out at length, all which will be easily understood by an inspection of the following figures.

Fig. 476. represents a small piece cut out of a walking cane, as it appeared in the microscope. A B E F shews a transverse section thereof, wherein are seen clusters of air vessels surrounded with rings of sap vessels, and at
A B C D

^a Phil. Transf. No. 904

A B C D the pores in the outside skin or bark of the cane are plainly visible.

Fig. 477. represents a magnified piece of the stalk of burdock cut transversely and down the side.

Fig. 478. exhibits a piece cut out of a branch of pine, wherein at A B C D is seen the bark side-ways, and at A B F E a transverse section thereof, through which the turpentine vessels run lengthwise. G H represents one of them cut down the middle to shew the inside of it, and another is seen intire at I K.

Fig. 479. represents the milk vessels in the bark of sumach, in the same manner as the turpentine vessels are represented in the foregoing figure, and are expressed by the same letters also.

Fig. 480. represents part of a vine branch cut transversely; and fig. 481. a piece cut out of the same at a b, as it appeared in the microscope; whereof A B C D shews the skin length-ways. At A B E F is seen a transverse section of the wood and air vessels, and between G H and I K part of the wood and bark is taken away to shew the same lengthwise.

Fig. 482. a, is a transverse section of an apple branch, in which the several circles of wood that shew of how many years growth the tree is, are visible to the naked eye. Fig. 482. b, represents a gore cut out of the aforesaid slice at a b, as it appeared in the microscope; in which A B represents the skin: A B C D the Bark: H I spiral sap vessels in arched parcels: O O the common sap vessels which begin to turn into wood: C D E F the wood of three years growth: K L M N one year's growth, in which the dark spots represent the air vessels: g g g the true wood: P P the insertions: E F other sap vessels: E F G the pith.

Fig.

Fig. 483. shews a transverse slice of a hazel branch, and fig. 484. represents a piece thereof, which was cut out at c d, as it appeared when placed in the microscope, A B the skin: A B C D the bark: Q Q Q the simple parenchyma: H I a ring of special vessels: P P common sap vessels: C D E F the wood of three years growth: K L M N one year's growth: X X X great insertions: P O lesser between them, the black parcels between these insertions are the wood, which is composed of minute tubes (although it is here represented in a shade) in which the dark spots are the air vessels: E F G the pith.

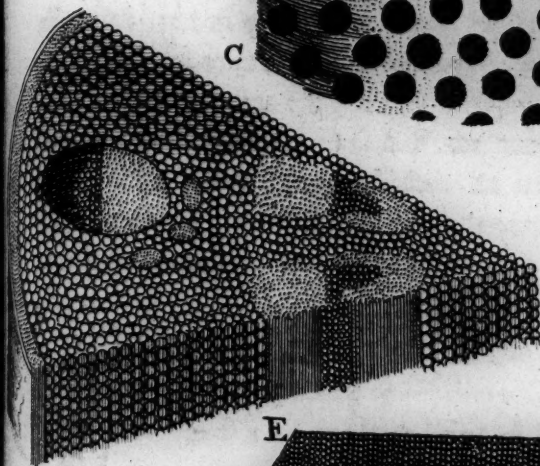
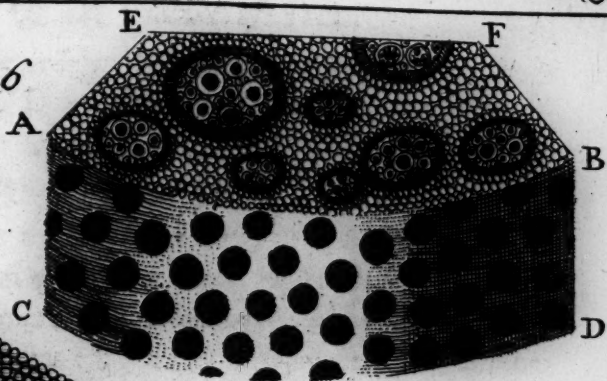
Fig. 485. exhibits a transverse slice of a walnut branch, and fig. 486. a microscopic picture of a gore thereof cut out from e f, in which A B is the skin: A B C D the bark: R R the parenchyma: H R I two rings of special sap vessels: D C common lymphæducts: D C E F the wood of four years growth: d d d the true wood: K L M N one year's growth; Q second part thereof whiter than the rest, by the mixture of sap vessels, which are represented by transverse lines: M N the great air vessels: c e, c e parcels of lesser ones: E F a ring of other sap vessels: E F G the pith.

At fig. 487. is seen a slice of a branch of pine cut transversely, and at fig. 488. a magnified piece of the same cut out from g h. A B C D the bark: M M M the parenchyma: D L C the lymphæducts: H H turpentine vessels: D C E F the wood in which the white spaces tending to the center shew the insertions: E F G the pith, the larger holes both in the wood and pith are more turpentine vessels.

Fig. 489. represents a transverse section of a wormwood stalk, from whence a piece i k was cut, which is exhibited as it appeared in the microscope, by fig. 490. whereof A B C D is the bark: A M B the parenchyma:

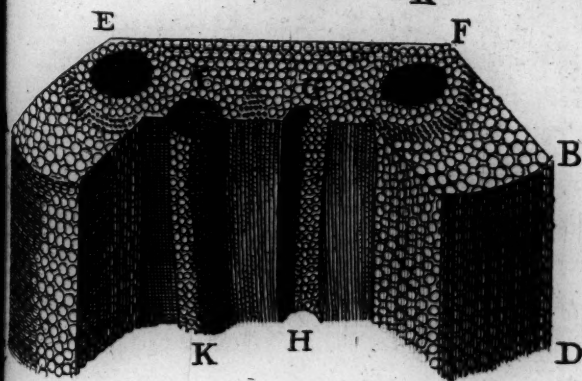
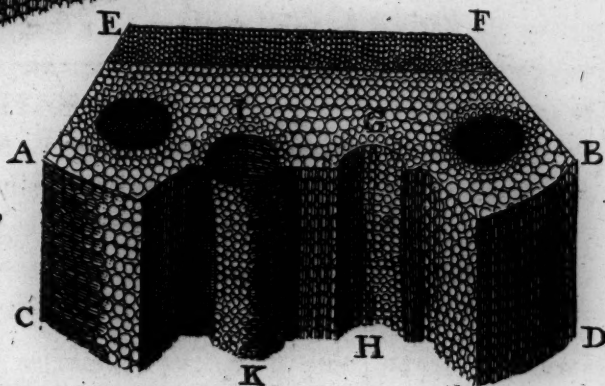
H M I

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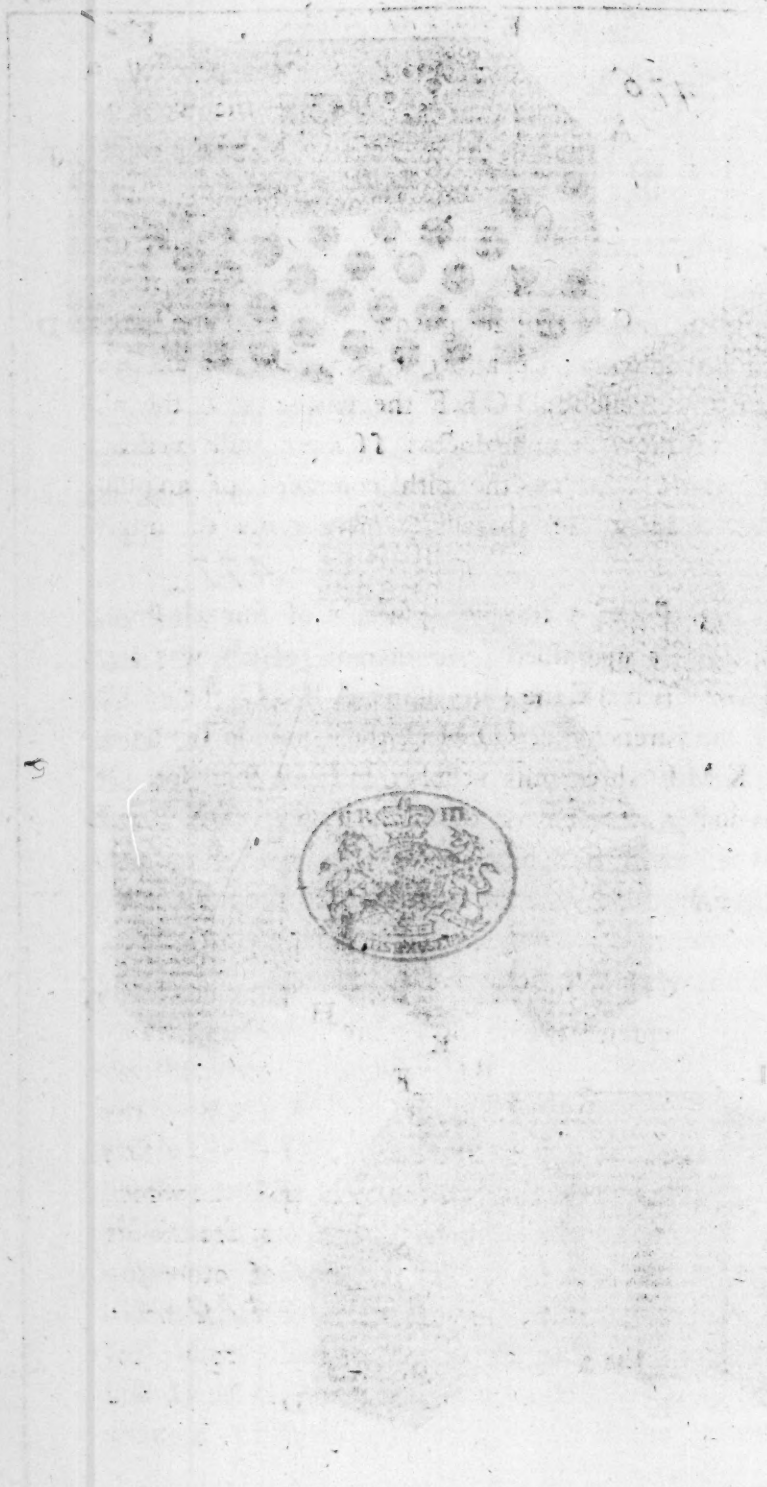
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H M I balsamic vessels: K L another sort of sap vessels in parcels: K L C D lymphæducts: D C E F the wood in which the dark spots, are the air vessels: M M the insertions: R another balsamic vessel: E F G the pith.

Fig. 491. is a transverse section of a thistle-stalk, out of which at l m was cut a piece, which is seen as it appeared in the microscope at fig. 492: A B C D the bark: H I the parenchyma: e e a sort of sap vessels: a a another sort: c c milk vessels: D C E F the wood: V V the air vessels: t t more lymphæducts: s s mere milk vessels: a t insertions: E F G the pith composed of angular bladders, bladders of threads, and threads of single fibres.

Fig. 493. shews a transverse section of sumach stalk, and fig 494. a magnified gore thereof, which was cut out at n o. A B a a the hairy skin: A B C D the bark: H W I the parenchyma: D M C the common lymphæducts: K M L three milk vessels: H I another sort of lymphæducts, arched over the milk vessels: X X seems to be a third sort of lymphæducts: D C E F the wood, the white rays tending from M to M are the insertions: Y Y the true wood in which the dark spots, are air vessels: E F a ring of lymphæducts: E F G the pith.

Fig. 495. represents part of a vine branch cut transversly at A B G, and A B C, and also split half way down the middle at G G B B, whereof A B A B is the skin: A B C D, A B C D the bark: H H H sap vessels in arched parcels: I the parenchyma: C D E F the wood: d d d the true wood, in which the dark spots, are the air vessels: K K the insertions: E F a ring of other sap vessels: E F G the pith: between G G, F F, is shewn the position of the bladders in perpendicular rows: between D D and B B is seen the same of the bark; and

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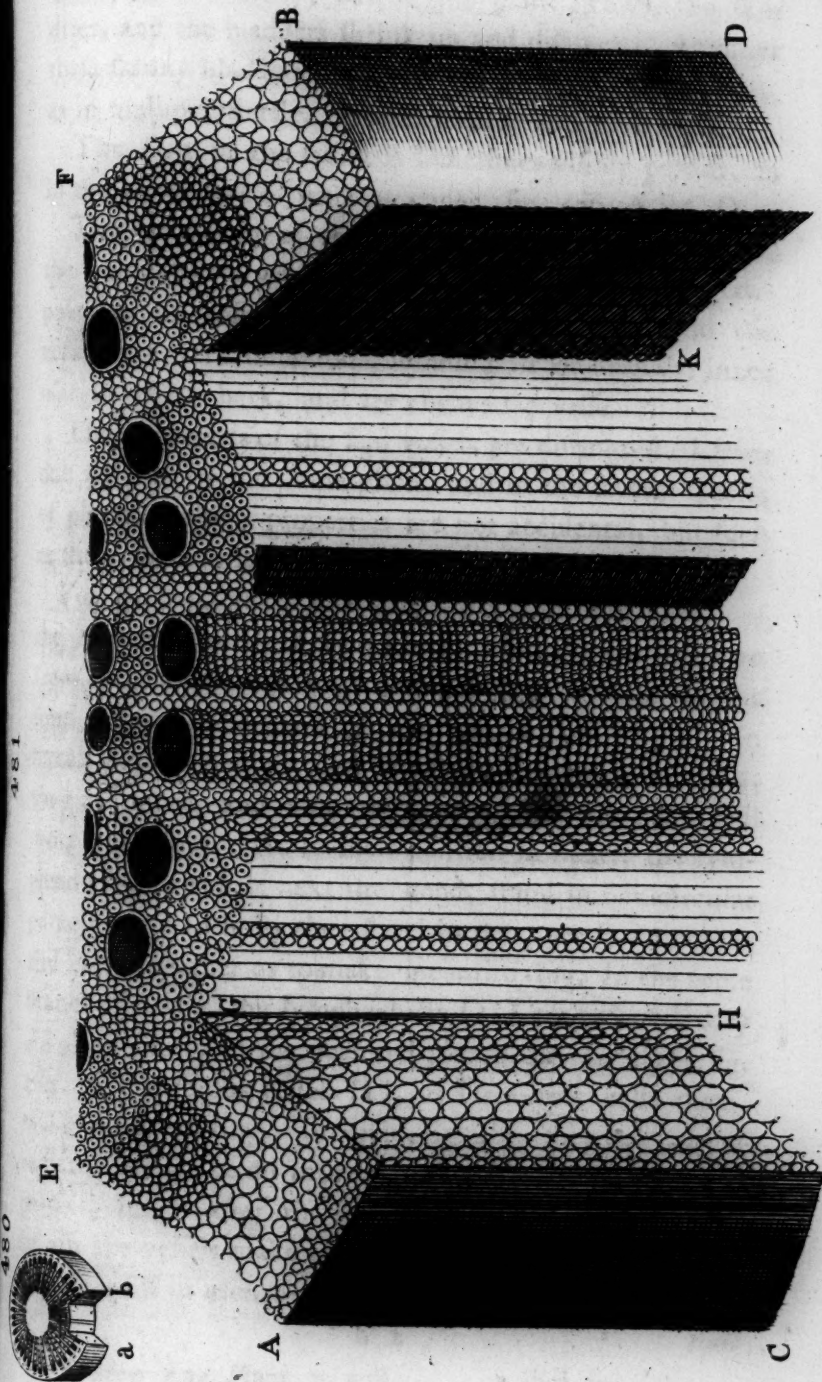
between

between F F D D is seen an upright section of the wood and air vessels.

Of the bark of trees.

THE exterior part of trees is the bark, and serves them for a skin or covering; in general it is of a spongy texture, and by many little fibres, which pass through the capillary tubes whereof the wood consists, communicated with the pith; so that the proper nutriment of the tree being imbibed by the roots, and carried up through the fine arterial vessels of the tree by the warmth of the soil, &c. to the top of the plant, is usually supposed to be there condensed by the cold air; and returns by its own gravity down the vessels, which do the office of veins, lying between the wood and inner bark, leaving, as it passes by, such parts of its juice as the texture of the bark will receive and requires for its support. That soft whitish rind or substance, between the inner bark and the wood, which, Mr. Bradley thinks, does the office of veins; some account a third bark, differing only from the others in the closeness of its fibres; it is this contains the liquid sap, gums, &c. found in plants in the spring and summer months. It hardens by little and little, by means of the sap it transmits, and is imperceptibly converted into the woody part of the tree. There are few trees but what have it; yet it is still found in less quantity as the tree is more exposed to the heat of the sun. It is here the corruption of trees generally begin; whence those who fell and cut trees ought always to take care to leave as little of it on as possible.

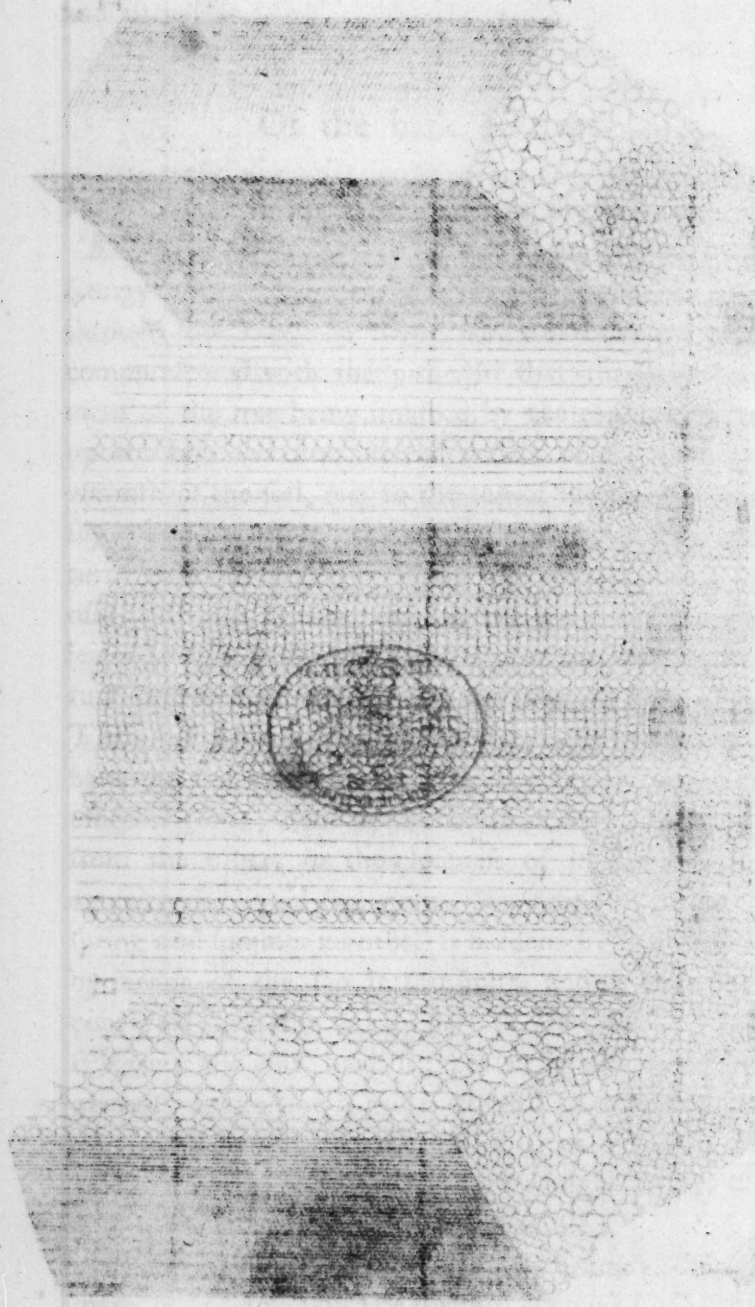
The bark consists of two parts, the utmost skin and the main body; the skin is generally composed of very small vesicles



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vesicles or bladders; but as the plant grows, the skin dries, and the bladders shrink up and disappear. Amongst these skinny bladders are intermixt a sort of woody fibres, as in mallow, nettle, borage, thistle, and most herbs.

The skin of the trunk is sometimes visibly porous, as in the better sort of walking canes, fig. 476. A B C D.

The main body of the bark also consists of two parts, the parenchyma and vessels; the parenchyma is composed of an infinite number of small bladders, and the vessels are very numerous, standing in or near the inner margin of the bark, and are always sap vessels °.

The properties of the said vessels are distinguished from one another in the same plant, and in the several species of plants; which properties are not accidental, but such as shew the constant and universal design of nature.

For in the figures 482, 484, 486, 488, the vessels of the bark are only of two kinds, which in the first two seem to be roriferous ^p and lymphæducts (yet in all the four their number and position is very different.) In hazel, fig. 484. they are but few; in apples, fig. 482. they are more, and also in pear, plumb, elm, &c. still more numerous. As to their position in hazel, the lymphæducts, or vessels next the wood, stand in semicircular parcels; and in holly they stand in rays, yet so numerous and close together as to make one intire ring. In the apple branch, fig. 482. the lymphæducts O O are radiated, they are also radiated in the pear and plumb, &c. In hazel, fig. 484. the roriferous vessels H I, as Dr. Grew calls them, make an entire ring. In apple, fig. 482. they are neither radiated nor make an intire ring, but stand in peripherical parcels, much after the same manner they stand in elm. In ash the vessels make two rings, the inmost or lymphæducts consist in arched parcels, and the outmost or rorife-

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° Grew Ana. Plant. p. 108.

^p Ibid. 109.

rous of round ones; whereas in the foregoing the lymphæducts are contiguous to the wood, and the roriferous more or less distant from the skin; here, on the contrary, the first are distant from the wood, and the latter contiguous to the skin.

In the two next branches, fig. 486 and 488. the vessels of the bark are also different in number, position, size and kind. In pine they are less, and in walnut more numerous; as to their position, the inmost D C in pine, fig. 488. compose a radiated ring, the utmost are straggling up and down without any certain order. In walnut, fig. 486. the inmost D C make also a radiated ring, and the outmost a double ring H R I, not radiated but of round parcels: as to their kind, they differ most apparently from the diversity of saps those different vessels contain; which in the bark of pine, fig. 488. are also of two sorts, the inmost are lymphæducts, as in the two former; the outmost are not milk, but gum vessels, or resiniferous, and stand straggling or singly about the bark; all the clear turpentine that drops from the tree issues from these vessels, which are apparent even to the naked eye; whereas those of the lymphæduct are not to be discerned without the assistance of a microscope.

The two next pieces of branches are common sumach, fig. 494. and common wormwood, fig. 490. which are remarkable for their having three kind of vessels in the bark, whereas the former have only two. First then in common sumach is a thick radiated ring D M C of lymphæducts, standing on the inner margin of the bark contiguous to the wood; these vessels exhibit their lymph very apparently. The second kind of vessels X X compose a ring, and are situate near the outward margin of the bark. Between these two kinds stand the milk ves-

sels

sels K M L, each of which being empaled or hemm'd in by an arch of roriferous vessels.

The next is a branch of common wormwood, fig. 490. in the bark of which are also three kinds of vessels; first there is a thin radiated ring C D L K of lymphæducts, contiguous to the wood, yet this ring is not entire, but made up of several parcels; which are intercepted by as many parenchymous ones, inserted from the bark into the pith. The second sort of vessels K L, which seem to be roriferous, are situate near the middle of the bark, and stand in arched parcels; these also compose a ring.

Beyond these arches, and towards the outer margin of the bark, stand a third sort of vessels H M I, their content is a kind of a liquid, oleous and viscid gum, which for its pleasant flavour may be called an aromatic balsam^s, because it perfectly affordeth whatever is in the smell or taste of wormwood, being the essence of the whole plant, so that they are in all respects analogous to the turpentine vessels in pine.

The structure of the milk and gum vessels when viewed with the microscope, seem to be made by the constipation of the bladders in the bark, that is to say, they are so many channels, not bounded by any sides proper to themselves, as a quill thrust into a cork, or as the air vessels in the wood, but by the bladders of the parenchyma^s, which are so crowded up together, as to leave certain tubular spaces throughout the whole length of the bark.

One difference between those vessels just described, and these hollow tubes, &c. in the pith, is this, that they are not originally formed with the pith, but are formed partly by the stretching it undergoes from the dilatation of the

S 3

wood

^s Grew Ana. Plant. p. 111.

^r Ibid. p. 113.

wood, and partly from the drying and shrinking up of its bladders, and of their component fibres; whereas the vessels in the bark are many of them originally formed therewith; and those which succeeded them are not caused by any rupture as those in the pith are, but from a regular disposition of the parenchymous fibres, and constipation of the bladders thereof; all which will appear very plain upon viewing the three figures 477, 478, and 479.

It has been before observed, that the lignous or towy parts of all plants are tubular, and that the juices are conveyed the whole length of the plant through an infinite company of small tubes.

These very tubes or lymphæducts are likewise made up of other yet much smaller tubes, set round together in a cylindrical figure; by which also appears the admirable smallness of these fibres; for there are some lymphæducts that may be reckoned fifty times smaller[†] than an horse-hair, and those minute fibres are also composed of other such fibres, but much smaller, is not altogether improbable; allowing therefore but twenty of these to compose a thread no bigger than one of these lymphæducts; then one of these fibres must be thousand times smaller than an horse-hair.

They may be observed in a very white and clear piece of ash torn carefully lengthways, and sometimes also in a very white piece of fir.

In the East Indies they manufacture the bark of a certain tree into a kind of stuff or cloth; it is spun and dressed much after the manner of hemp: the long filaments which are separated from it, upon beating and steeping it in water, compose a thread of a middle kind
between

[†] Grew. Ana. Plant. p. 113.

[†] Ibid. p. 112.

between silk and common thread, neither so soft or bright as silk, nor so hard or flat as hemp. Some of these stuffs are pure bark, and are called pinasses, biambonnes, &c. In others they mix silk with the bark, and call them gingham and nillas; the fontalungees too, are part silk, part bark, and are only distinguished by being striped.

Of the wood.

THE next general part of a branch is the wood which lies between the bark and pith; it is composed of parenchymous and lignous parts. The parenchymous part of the wood in all trees, though much diversified, is disposed into many rays or insertions running between as many woody portions, from the bark to the pith. These insertions are various according to the several sorts of trees or plants, in pine, fig. 488, and wormwood, fig. 490. they are not so numerous as in sumach, fig. 494. in the apple, fig. 482. or in the hazel, fig. 484.

These insertions do not run only through the wood, but also shoot out beyond it into some part of the bark, as in elm, sumach, wormwood, &c.

The texture likewise of these insertions is also various in wormwood and most herbs, they are manifestly composed of small bladders, yet larger in these than in trees.

The wood is likewise composed of two sorts of bodies, that which is strictly woody, and the air vessels. The true wood is nothing else but a mass of antiquated lymphæducts, viz. those which are originally placed on the inner margin of the bark; for in that place there annually grows a new ring of lymphæducts, which by de-

grees losing its first softness, is at the latter end of the year turned into a dry and hard ring of perfect wood. Whence it is evident that the bark of a tree is divided into two parts, and distributed two contrary ways; the outer part falleth off towards the skin, and at length becomes the skin itself. The outward skin of a tree is not originally made a skin, but was once some of the middle part of the bark itself, which is annually cast off and dried into a skin; the inmost portion of the bark is yearly distributed and added to the wood, the parenchymous part thereof makes a new addition to the insertions within the wood, and the lymphæducts a new addition to the woody pieces between which the insertions stand; so that a ring of lymphæducts in the bark this year will be a ring of wood the next, and another ring of lymphæducts and of wood successively from year to year; so in fig. 482. of part of an apple branch cut transversly, three years growth are represented in that of sumach, fig. 484. one year only is exhibited, and in that of walnut, fig. 486. are shewn four years growth of wood between the letters D C E F.

Here also may be observed, that certain parcels of wood make either several small white rings, as in oak, or several white and crooked parcels transverse to the insertions, as at D C, K L, &c. in walnut, fig. 486.

In the branches of fir, pine, &c. are a few turpentine vessels dispersed up and down the wood. The air vessels with the insertions, and true wood altogether, make up that which is commonly called the wood of a tree.

The variety of the air vessels are many, with respect both as to their number, size, and position, and are not to be found alike in any two sorts of plants whatsoever: as to their number it is very great, in apple, pear, hazel, &c. but in different degrees, they are represented by all the

the black spots in the wood, in all the figures before referred to.

Their sizes are as different as the trees to which they belong, being at least twenty times bigger in elm or oak, than in holly or pear, &c.

Their situation is also different: in apple, fig. 482. and in walnut, fig. &c. they are spread abroad in every annual ring; in others they keep more in the compass of some line or lines, either diametrical or peripherical. In holly, &c. they are radiated or run in even diametrical lines between the pith and bark.

Whether the air vessels are irregular or radiated, nature hath so disposed them, as that many of them stand always near the insertions.

In ash the air vessels stand in circles on the inner margin of every annual ring. These circles are in some very thick, as in ash and barberry, in some thin, as elm, &c.

Their form is such that they are never ramified, but continued from one end of a plant small or great, quite through to the other end thereof.

As to their texture they oftentimes appear to be unwreathed in form of a very small plate, which also is not only of different breadths in different plants, and usually broader in the root than in the trunk; but also the said vessels are oftentimes unwreathed, not in the form of a plate but of a round thread. The causes of which diversity are principally three, the westage of the fibres of which the air vessels consist; the difference between the said fibres, or between the warp and woof, and the different kinds of woof.

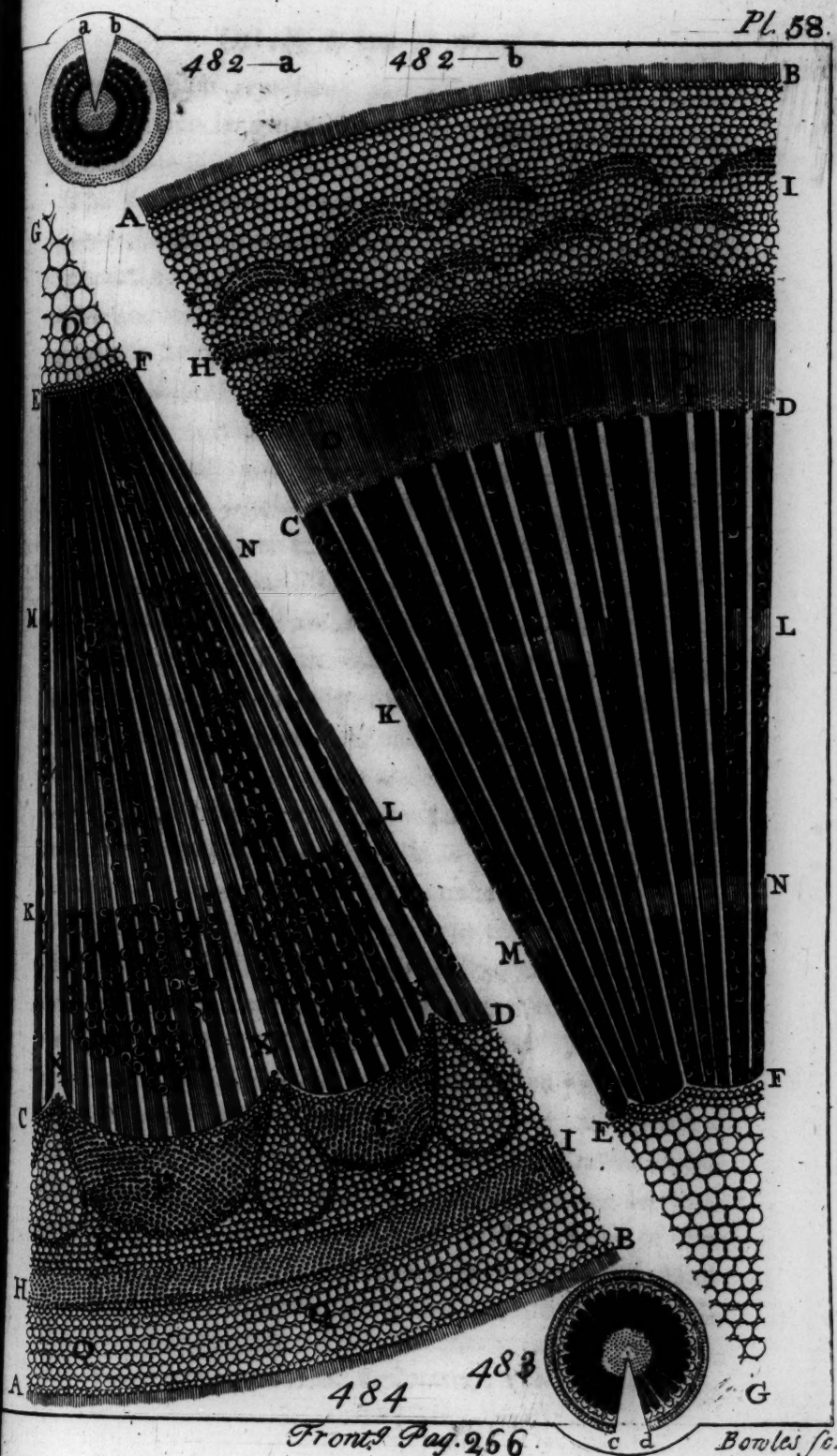
By the westage of the fibres it is, that the vessels oftentimes untwist in the form of a plate; as if a fine narrow ribband be wound spirally, and edge to edge, about a stick,

stick, and then the stick being drawn out, will leave the ribband in the form of a tube " and of one of these air vessels, for that which upon the unwreathing of the vessel seems to be a plate, is as it were a natural ribband, consisting of a certain number of threads or round fibres, standing parallel as the threads do in a ribband; and as in a ribband so here, the fibres which make the warp and run spirally, do not grow together, but are held in that position by other transverse fibres which embrace them, and are in the place of the woof.

And as the said fibres are transversely continued, thereby making a warp and woof, so are they (as in divers woollen manufactures) of different bulk; those of the former being stronger and bigger than those of the latter; by which means, as cloth and silk will usually tear sooner one way than another; so here while the warp, or those fibres which run spirally are unwreathed, without breaking the smaller ones which hold them together, easily tear all the way.

In the following figures are shewn the position of the vessels in several sorts of timber cut length-wise and cross-wise as follows:

Fig. 507. represents a small piece of the wood of an oak-tree, cut transversely, and of its natural size; and fig. 508. A B C D, shews the same piece as it appeared before the microscope when greatly magnified, whereof the parts F F seemed to be brown dark streaks, the wood included between the spaces H I and K L, is the breadth of that circle which the tree had increased in one year. E E are the cavities of very large air vessels, which run the lengthway of the tree. These large vessels are composed of several smaller membranes, as may be seen at



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fig. 512. which represents part of one of the aforesaid air vessels seen length-wise, and as it appeared before the magnifier.

The second sort of perpendicular vessels which tend upwards, are seen at e e, fig. 508. and are also composed of exceeding fine skins^z, in which are seen some spots that in the microscope appear like globules, as at O N, fig. 511. which shews one of these second sort of vessels cut lengthwise.

The third sort of these vessels which run upwards, are extremely small and in great abundance, as appears throughout the whole space H I K L, fig. 508. These also are composed of extremely fine skins; they are seen length-ways between P Q, fig. 511.

G G G, fig. 508. are another sort of vessels, which run horizontally from the bark to the pith: these seemed to extend themselves in furrows, and were crooked or bowed round the knots. When the wood is cut length-wise, these horizontal vessels are cut across, as at G G G, fig. 511. The second sort of horizontal vessels are greatly numerous, which when the oak is cut length-wise, are also cut across, and appear to the naked eye as fig. 513.

Fig. 496. shews a piece of elm cut transversly as it appeared to the naked eye; and fig. 497. a microscopic picture of the same. A B, C D is the breadth of the ring the tree had increased in one year. The smaller perpendicular vessels are situate between and joined to the larger, having smaller ones between them, as in oak; the tubes here also are composed of skinny membranes. A C and B D, fig. 497. are horizontal vessels seen length-wise. Fig. 498. is an upright section of the wood of elm magnified, in which G G shews the exceeding small vessels

^z Leeuwenhoek's Anat. & Contemp. Vol. I. p. 3.

vessels length-ways, H H is the cavity of one of the great vessels, being full of turpentine threads, or little tubes, with black spots curiously wove together; as at fig. 499.

Fig. 500. is a small and thin piece of beach, cut transversely, and fig. 501. represents the same as it appeared in the microscope. Its length between A B and D C is the breadth of a circle of one year's growth. The perpendicular vessels in this wood are of two, the horizontal ones of three sizes; of which those expressed by E E, fig. 501. are exceeding small; in the upright section, fig. 502. these horizontal vessels are cut transversely, and shewn by H H, the second sort of horizontal vessels are seen lengthwise, from D to A, fig. 501. and a transverse section of the same vessels are seen in the upright section of the timber, fig. 502. at I, I, I, and at K K are seen the great perpendicular vessels.

Fig. 509. represents a transverse section of a small bit of black ebony, greatly magnified, of which G, G, G, are the large upright vessels. K K, in fig. 510. shews one of these large vessels cut lengthwise, and at fig. 511. is seen another of a larger sort, in which are many streaks and spots. The second sort of perpendicular vessels are seen between A B, A B, and the third sort between C D, C D; a fourth sort are squarish, and included between the second and third in the upright section, fig. 510. L L shews the smallest vessels, and I, I, the transverse sections of the horizontal ones.

Fig. 503. A B C D is a small piece of box, cut transversely, and of the same size to the naked eye as the piece of ebony. This wood also consists of large and small perpendicular vessels intermixed; the large ones are composed of skins, and are full of extremely minute particles, as may be seen in the upright section thereof at E E, fig. 504. the cavities of the lesser vessels are shewn lengthways

at

at FE. AB and CD, fig. 503. are horizontal vessels, running lengthways, and at GG, fig. 504. is seen a transverse section of the same.

ABCDEF, fig. 505. represents a transverse section of a small piece of straw. AB EF is the shining bark, composed of an incredible number of exceeding small vesicles. GG GG are vessels, or rather bladders, having four, five, or six sides, and compose the greatest part of the inside of the straw. HHH are some of the before-mentioned vessels, intermixed with, or surrounded by a great number of exceeding small vessels. At fig. 506. the same vessels are seen lengthways in a perpendicular section of the straw.

Of the pith.

THE third general part of a branch is the pith, being in substance nearly allied to the parenchyma in the bark, and the insertions in the wood.

Its size is various, not being the same in any two branches here represented. In wormwood, fig. 490. and sumach, fig. 494. it is very large. In pine, fig. 488. and walnut, fig. 486. not so large. In apple, fig. 482. and hazel, fig. 484. it is smaller.

It is also remarkable, that the bark and wood in most plants increase yearly; and the pith, on the contrary, grows smaller.

The pith, for the most part, is furnished with a certain number of sap vessels, which form a ring round the margin thereof. They are numerous and conspicuous in walnut, fig. 486. and in pine, fig. 488. &c. and are of divers kinds, being lymphæducts in walnuts, lacteals in fig, and resiniferous in pine.

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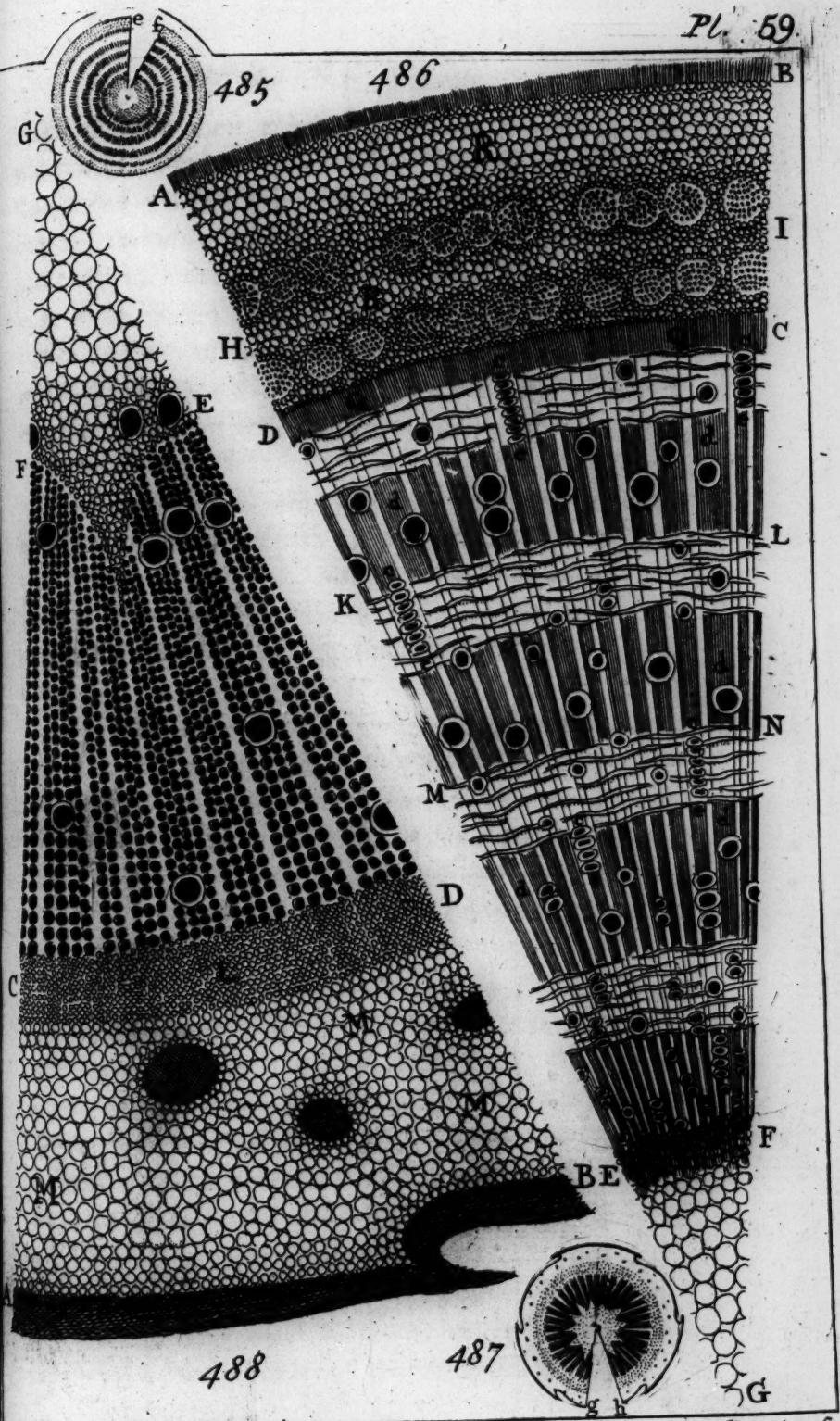
The parenchyma of the pith is composed of bladders the very same with those in the bark, and oftentimes in the insertions within the wood; only these of the pith are largest, those in the bark less, and these in the insertions least of all.

The bladders of the pith, though always comparatively great, are of very different sizes. Those of thistle, borage, &c. appear in the microscope like the cells of an honey-comb; the bladders in common thistle and borage, are so large as to contain within their horizontal area, about twenty bladders of the pith of oak. Wherefore one bladder in thistle is at least an hundred times bigger than another in oak.

The shape of the pith bladders admit of some variety; they are for the most part round, yet oftentimes angular, as in reed grass, a water plant; where they are also cubical; in borage, thistle, and many others they are pentangular, sexangular, and septangular.

As to the texture of these pithy bladders, they are oftentimes composed of smaller ones, as in borage, bulrush, and many other plants.

Whence it appears, that as the vessels of plants, viz. the air vessels and lymphæducts, are made up of fibres, so the pith, or the bladders of which the pith consists, are likewise composed of fibres, which is also true of the parenchyma of the bark, and of the insertions in the wood, and even of the fruit, and all other parenchymous parts of a plant, and that the very pulp of an apple, pear, cucumber, plumb, or any other fruit, is nothing else but a ball, of most extremely small transparent threads or fibres, joined together in a different, but curious manner, even all those parts of a plant, which are neither formed into visible tubes, nor bladders, are made up of fibres; and though it be difficult to discover them in those parts
which



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which are the most compact and close, yet in the pith which consists of more open work, they are visible; and that in the pith of a bulrush, common thistle, &c. not only the threads of which the bladders, but also the single fibres of which the threads are composed, may be distinctly seen, when placed before the microscope.

The fibrosity of the parenchyma is also visible in some woods, being interwove with the lignous parts, and with every fibre of every vessel, as in very white ash or fir, may be discovered.

Whence it follows, that all the parts of a plant consist of fibres, of which those of the lymphæducts run lengthwise, those of the pith, insertions, and parenchyma of the bark horizontally, those of the air vessels begin their circuit horizontally, and continue it in height or lengthwise.

From what has been said, there appears to be a great similitude between the mechanism of plants and animals, the parts of the former seem to bear a constant analogy to those of the latter; and the vegetable and animal œconomy seem to be both formed on the same model; for from the foregoing observations, and the assistance of the microscope,

First, the root is found to be a spongy body, whose pores are disposed to admit certain humid particles, prepared in the ground.

Second, the wood which consists of capillary tubes running parallel from the root throughout the stalk, (the apertures of those tubes are too minute to come under the cognizance of the naked eye) these Mr. Bradley calls arterial vessels; it being through these that the sap rises from the root.

Third, besides these there are other larger vessels, disposed on the outside of the arterial vessels between
the

the wood and the inner bark, and leading down to the covering of the root, which he also calls venal vessels, and supposes them to contain the liquid sap found in plants in the spring.

Fourth, the bark being of a spongy texture, which by many little strings communicates with the pith.

Fifth, the pith, or pecten, which consists of little transparent globules, chained together somewhat like the bubbles that compose the froth of liquor.

Malpighi was the first who observed, that vegetables consist of two sorts of vessels. 1. Those abovementioned, which receive and convey the alimential juices. 2. Tracheæ, or air vessels, which are long hollow pipes, wherein air is continually received and expelled, i. e. within which tracheæ he shews all the former series of vessels are contained.

Hence it follows, that the heat of a year, nay of a day, of a single hour, or minute, must have an effect on the air, included in these tracheæ, i. e. it must rarify it, and consequently dilate the tracheæ; whence also must arise a perpetual spring or force of action to promote the circulation in plants.

For by the expansion of the tracheæ, the vessels containing the juices are pressed; and by that means the contained juice is continually propelled, and so accelerated; by which same propulsion the juice is continually comminuted and rendered more and more subtle, and so enabled to enter vessels still finer and finer; the thickest part of it being at the same time secreted and deposited into the lateral cells, or loculi of the bark, to defend the plant from cold and other external injuries.

The juice being thus conveyed from the root, to the remote branches, and even to the flower; and having in every

every part of its progress deposited something both for aliment and defence, what is redundant passes out into the bark, the vessels whereof are insculcated with those wherein the sap is mounted; and through these it descends to the root, and thence to the earth again, and thus is circulation effected.

Thus is every vegetable acted on by heat during the day-time, and the sap vessels thus are squeezed and pressed, and the sap protruded and raised, and at length evacuated, and the vessels exhausted in the night again; the same trachea being contracted by the coldness of the air, the other vessels are eased and relaxed, and so disposed to receive fresh food for the next day's digestion and excretion.

The juice being carried on to the germs or bud, is more concentered; and here having unfolded the leaves, which being exposed to the alternate action of heat and cold, moist nights, and hot scorching days, are alternately expanded and contracted; and the more on account of their reticular texture.

By such means the juice is farther altered and digested, as it is further yet in the petala, or leaves of the flowers, which transmit the juice, now brought to a further subtilty to the stamina; these communicate it to the farina, or dust in the apices, where having undergone a farther maturation, it is shed into the pistil, and here having acquired its last perfection, gives rise to a new fruit or plant.

Fig. 514. and the four following figures, represent the structure of the woody fibres and lymphæducts both in the bark and wood.

Fig. 514. shews a single vessel in the bark of flax; and fig. 515. represents the same vessel as seen in the microscope, and greatly magnified; whence it appears to be

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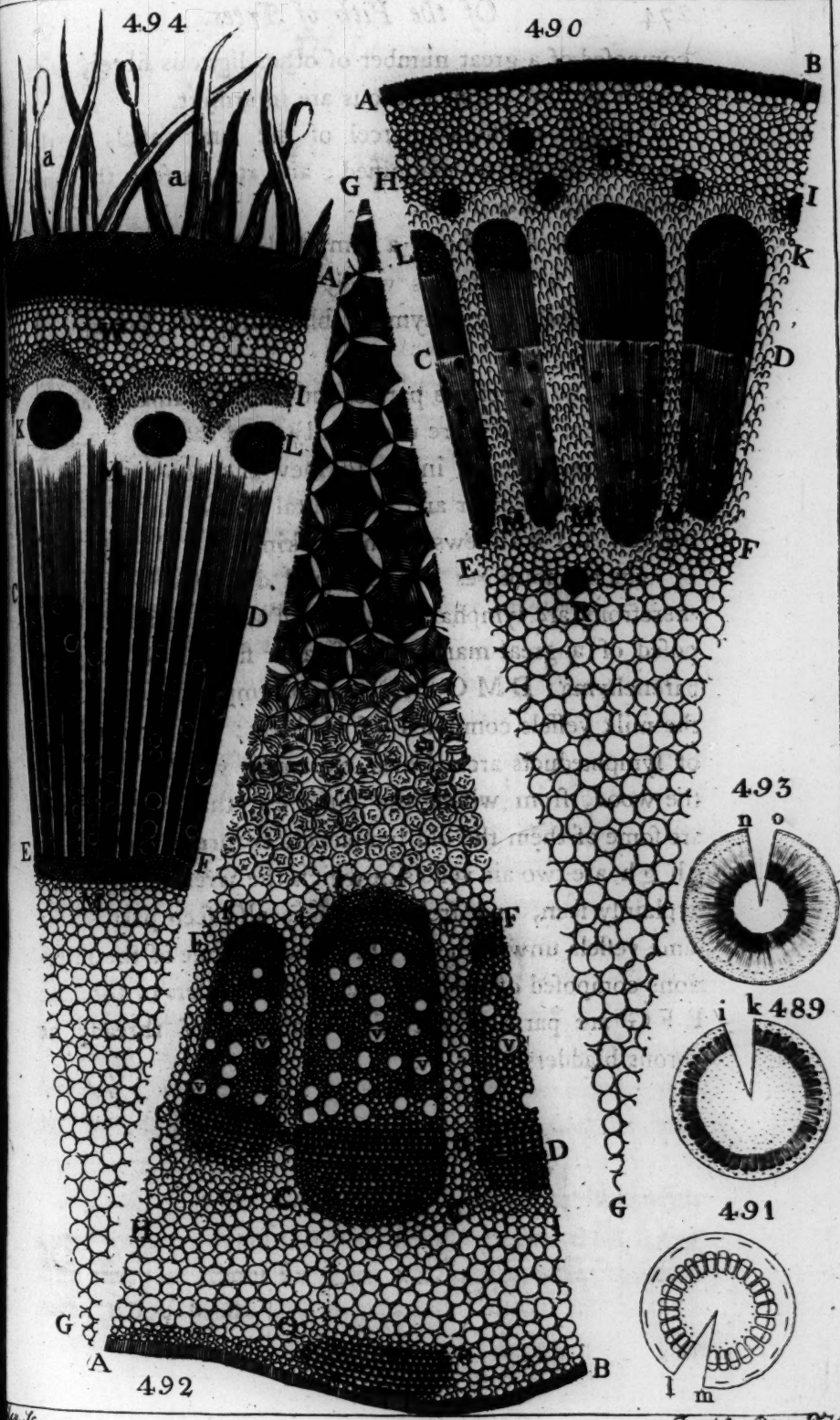
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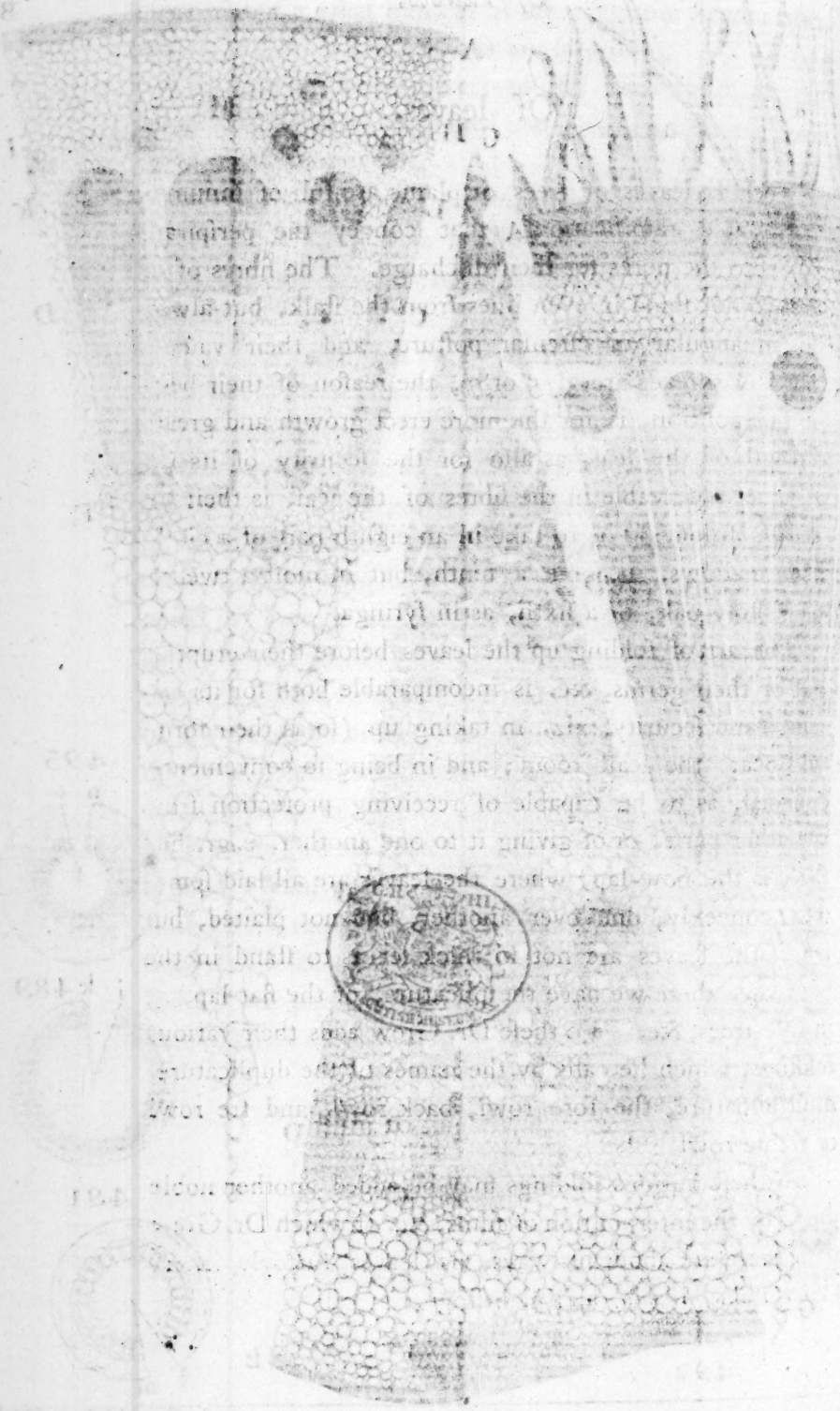
composed of a great number of other lignous fibres, with which also the parenchymous are intermixt.

Fig. 516. exhibits a parcel of the same vessels in the wood of fir, greatly magnified; and at a, is seen the same piece of its natural size.

Fig. 517. A B shews a lymphæduct, and fig. 518. C, represents a lactiferous vessel, both of which are surrounded with parenchymous bladders, and are greatly magnified.

Fig. 519. represents part of the stalk of sumach, somewhat larger (and more magnified) than that of fig. 494. with several breaks in it, to shew the contexture both of the perpendicular and horizontal fibres; in which, as before, A B a a shews the hairy skin: A B C D the bark in which the fibres b b, c c, and d d, that hang down therefrom, are lymphæducts, one of which d d d, is composed of a great many other smaller fibres: H W I the parenchyma: D M C the common lymphæducts: K M L the milk vessels composed of bladders: H I another sort of lymphæducts arched over the milk vessels: D C E F the wood, from which the fibres e f, that hang down, are some of them the old lymphæducts turned into wood: g h g h are two air vessels in which the wreathing thereof is plainly seen, and from h to i is also seen part of the same vessels unwreathed: O P is part of one of the interstitions composed of bladders, and those bladders of threads: E F G are parts of the pith composed of thready or fibrous bladders.





Of leaves.

THE leaves of trees or plants are full of innumerable ramifications, that convey the perspirable juices to the pores for their discharge. The fibres of the leaf do not stand in even lines from the stalk, but always in an angular or circular posture, and their vascular fibres or threads are 3, 5 or 7; the reason of their being in this position, is for the more erect growth and greater strength of the leaf, as also for the security of its sap. Another observable in the fibres of the leaf, is their orderly position, so as to take in an eighth part of a circle, as in mallows, in some a tenth, but in most a twelfth, as in holy-oak, or a sixth, as in syringa.

The art of folding up the leaves before their eruption out of their germs, &c. is incomparable both for its elegance and security, viz. in taking up (so as their forms will bear) the least room; and in being so conveniently couched, as to be capable of receiving protection from the other parts, or of giving it to one another, e. gr. first there is the bow-lap, where the leaves are all laid somewhat convexly, one over another, but not plaited, but where the leaves are not so thick set as to stand in the bow-lap; there we have the plicature, or the flat lap, as in rose-trees, &c. To these Dr. Grew adds their various foldings, which he calls by the names of the duplicature, multiplicature, the fore rowl, back rowl, and tre rowl or treble rowl.

To these curious foldings may be added another noble guard by the interposition of films, &c. of which Dr. Grew saith there are about six ways, viz. leaves, surfoyls, interfoyls, flaks, heads, and mantlings.

The various methods which nature takes to preserve the leaves from the injuries both of the ground and weather are, viz. the young buds of ammi, at their first eruption from the ground, are couched, as fern is rowled inward; each bud, against the brace of the stalk of the foregoing leaves, and most exactly inclosed in the membranes thence produced. Nature hath generally provided them with another protection, where the stalks of the leaves are so long that they cannot lap over each other, the bottoms of the stalks are expanded into broad membranes, as in crows-foot, doves-foot, clover, cranhill, strawberry, harrow, &c. and sometimes instead of two skins lapped over each other, one entire skin is produced from the stalk, in which, as within a secundine, the bud is safely lodged, which it gradually breaks open in its growth.

It is also observable in dock, sorrel, bistort, and all other plants of this sort, with this difference, that every veil or secundine is not here produced from the stalk of the leaf; whereas in the former every bud hath one to itself in these plants, every lesser leaf, together with its own proper veil, is always inclosed with the next greater leaf in another common to them both, and both these with the next in another, and so on to the greatest. The orchis, and other plants of this sort, have a double sheath over all. The buds of some herbs as plantain, having no hairs growing over them, are covered with hairy thrums, and the nettle hath bastard-leaves or interfoyls between leaf and leaf, for the preservation of its stings.

Another sort of protection is seen in white archangel, and other plants of a like shape. In which the greater leaves do also inclose the lesser, by a double fore curl at the bottom of every two great leaves, which embraces

braces the little under bud, and so keeps it clean and warm.

The leaves of onions are all pipes one within another, having a small aperture about the middle common to all of them, even the most minute ones in the center.

As the buds of common sumach are exceeding tender, nature appears in a peculiar manner solicitous for their preservation, being lodged within the body of the stalk, as entirely as a kernel is within an apple; from whence it is that the basis of every stalk is extremely swelled.

There are also globular excrescencies, spots, hairs, thorns, and prickles.

Globulets are seen upon orach, but more plainly upon *bonus henricus*, in these growing almost upon the whole plant, and being very large, are by most people taken notice of; but the microscope hath discovered to us that they are the natural and constant offspring of very many other plants, they are of two kinds transparent, as upon the leaves of hyssop, mint, baume, &c. white on german-der, sage, &c. Sometimes they appear like a fine powder upon the leaf, these were first white and transparent as in bear's ear. If this be licked of, it will afford the taste of the essential content of the plant. They frequently grow on both sides the leaf, yet sometimes, as in ground-ivy, chiefly on the back side thereof, and in many plants where the elder-leaves have none, on the young buds they are very numerous, as in corin-tree, sorrel, and others.

Spots are observable in St. John's-wort, rue, ground-ivy, pimpernel or anagallis, &c. when held up against the light.

Thorns are lignous and cortical, the first are such as those of hawthorn, somewhat like these are the spinets or

thorny prickles, upon the edges and tops of divers leaves, as barberry, holly, thistle, furz, &c.

Cortical thorns are such as those of the raspberry-bush, being not, unless in an invisible proportion, propagated from the lignous body. They are of use not only for the protection of the bud, but also for the support of the plant.

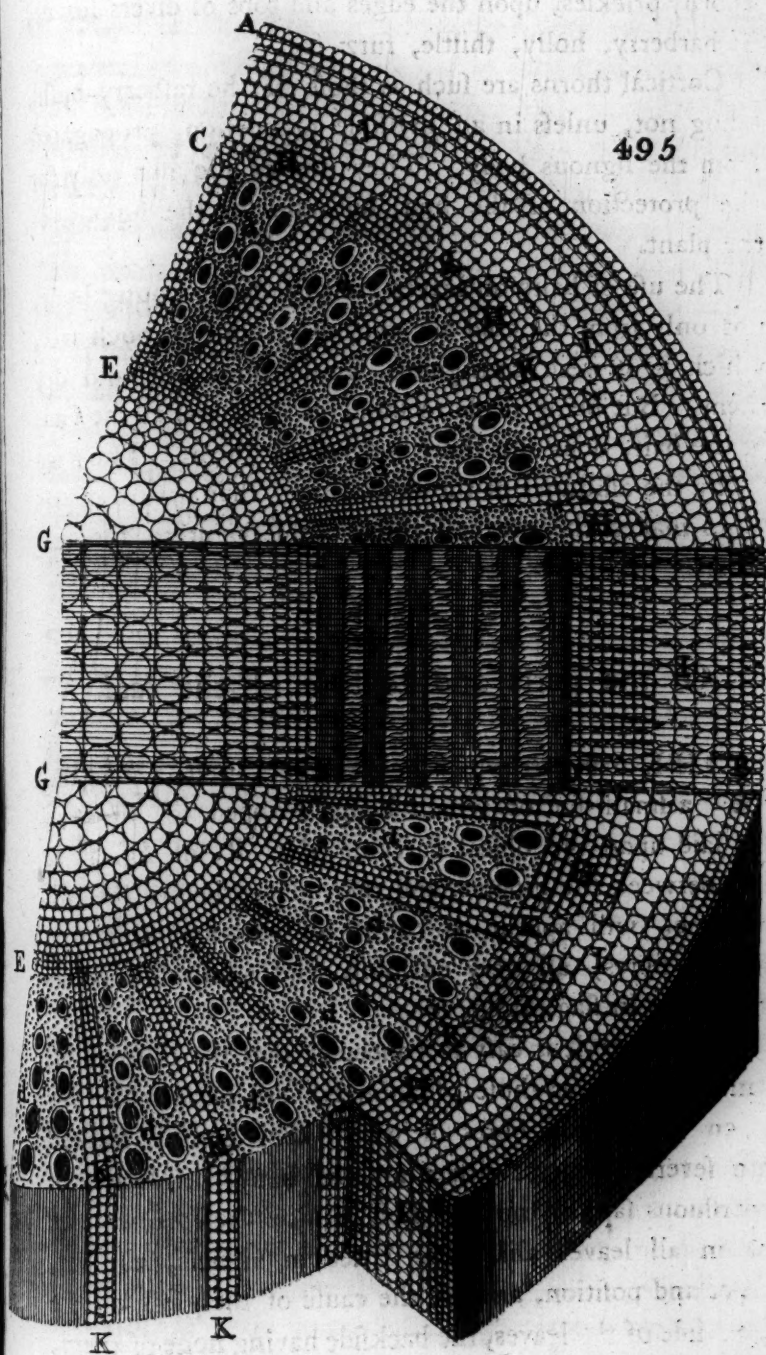
The use of hairs on leaves are to preserve young buds, not only from the cold air, but also from too much wet, which if it were contiguous would often rot and dry them. But being made to stand off in drops, at the ends of the hair, does not hurt but refresh them. Thus we see by the assistance of the microscope, that nature oftentimes makes the meanest things subservient to the best ends.

Of the parts and texture of the leaf.

THE first part which here presents itself is the skin, a small bit of which being stripped off the leaf, and laid upon the object carrying glass R, of fig. 2. or held between the nippers, and then placed before the microscope, will appear to consist of parenchymous and lignous fibres, all very curiously and admirably interwoven, as in flag, tulip, &c.

From hence it is easy to conceive, that the skins of all plants (as well as those of animals) are perspirable between the several fibres of which they consist, formed into several orifices, either for the better avolation of superfluous sap, or the admission of air; these orifices are not in all leaves alike, but varied in bigness, number, shape, and position, and are the cause of the gloss on the upper-side of the leaves, the backside having none of them.

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Next the skin lies the pulpy part of the leaf, called the parenchyma, being composed of an incomparable number of little cylindrical fibres, which are in most leaves wound up into minute bladders, but generally more visible in the stalk than in the body of the leaf. In some leaves, as in borage, fig. 520. the greater bladders are made up of lesser ones, and in some others these parenchymous fibres are all drawn up close together.

The pithy part in the stalk, and almost up to the top of the chief fibre, in many leaves is tubular, even whilst they are yet young and sappy, as in sweet cervil, hemlock, endive, cichory, lampfana, dandelion, burdock, daize, scorzonera, and others, and sometimes the said pithy part is opened into several pithy pipes; the fibres also of the leaf, which is visible to the naked eye, are composed of sap and air vessels. Their position is various and regular, not only in the body of the leaf, but likewise in the stalk, as in the stalk of a mallow-leaf, fig. 521. they stand in six oblong parcels of equal size, and in a circle near the circumference. In dandelion, wild clary, and in borage, fig. 522. they stand in five parcels.

In the body of the leaf, besides the positions of the fibrous strings, there is one in particular which runs round the edge of the leaf in all plants; but can hardly be well discovered without stripping off the skin of the leaf. The continuation of the vessels seem to be ramified, and seem also to be inosculated.

These tracheæ or air vessels are visible, and appear very pretty in the leaf of scabious, or the vine, by pulling asunder some of its principal ribs or great fibres; between which may be seen the spiral air vessels (like threads of a cob-web) a little uncoiled, as represented by fig. 523. which shews a piece of a vine-leaf, wherein these vessels

were drawn out and a little magnified, and at a the spiral circumvolutions are represented as they appeared in the microscope when greatly magnified, and as they stand intire within the wood; and at b is seen one a little stretched.

Mr. Leeuwenhoek tore a leaf of box to pieces, called palma cereris, that he might the better examine it, and computed one side thereof to contain 172090 pores, and as the other side must consequently have the same number, the whole pores in a box-leaf will be 344180.

Of rosemary-leaves.

FIG. 524. represents a small part of the under-side of a rosemary-leaf ^y, whereof A B shews part of the upper side which was doubled over, and consisted of a smooth shining substance, but its under-side appeared in the microscope like a thicket of bushes, amongst which were a great number of round balls, exactly globular, and afford a very agreeable prospect.

The back-side of a rose-tree leaf, but especially of a sweet briar leaf, looks diapered with silver.

The back of the leaf of English Mercury ^z looks as if rough cast with silver, and all the ribs set round with white transparent balls.

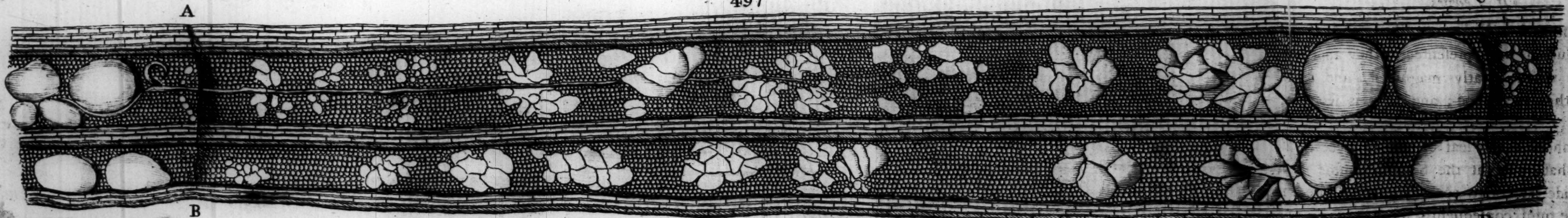
A leaf of rue looks full of holes like an honey-comb.

A sage-leaf is tasseled with white silver thrums, and one or two crystal beads, or pendants, fastened to every knot.

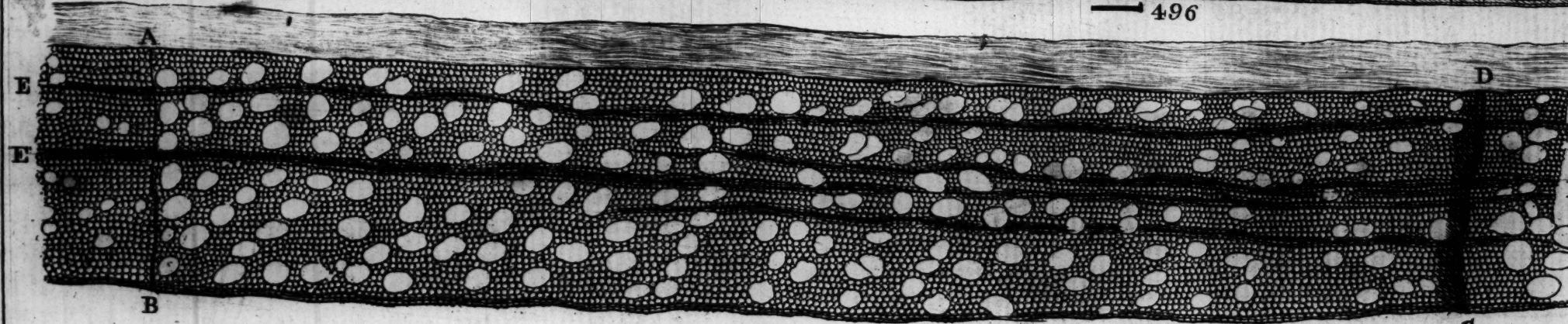
^y Hook's Mic. p. 142.

^z Power's Mic. Obs. p. 50.

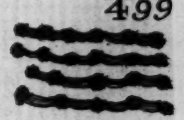
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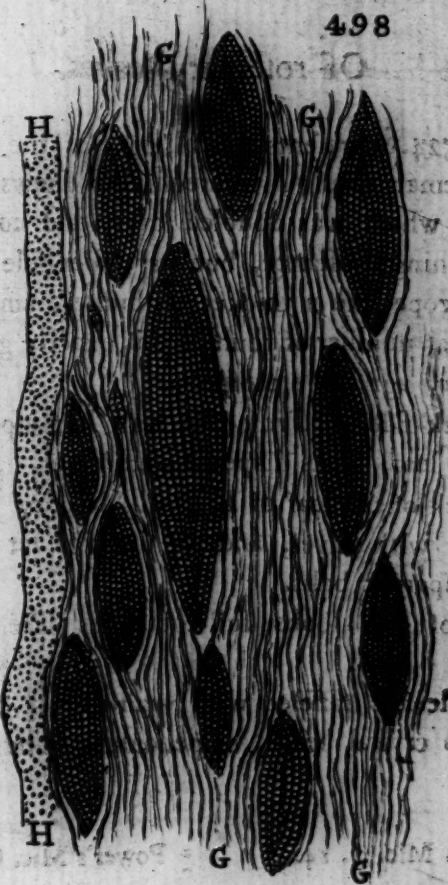
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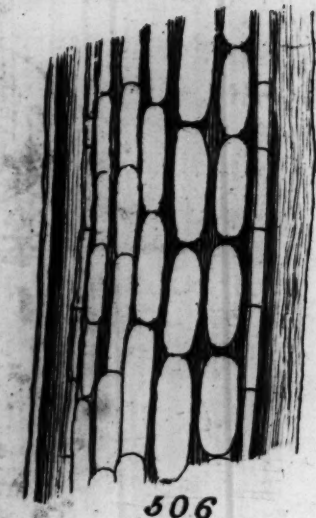
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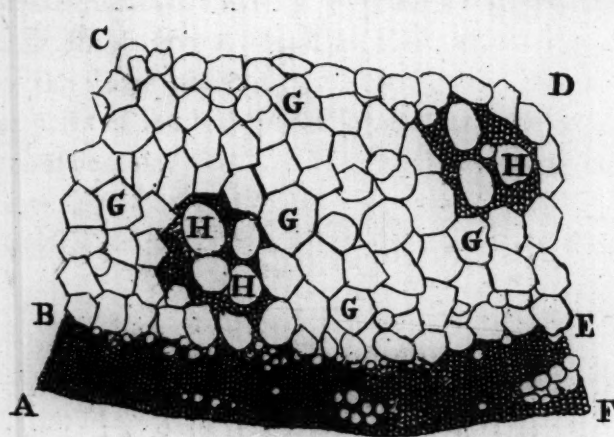
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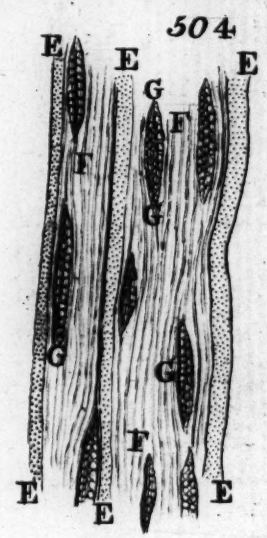
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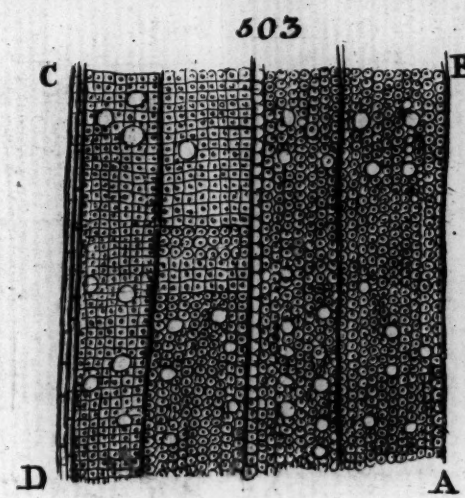
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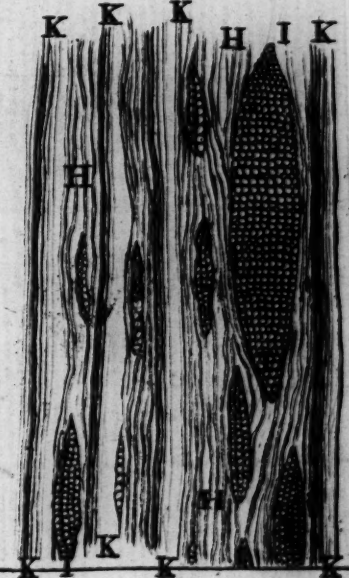
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Of stinging-nettles.

A Nettle is a plant known almost to every body, there being very few but what have felt as well as seen it; but how the pain is so suddenly created, and by what means continued, we must have recourse to the microscope for our information, and that will, if almost any part of the plant be looked on, shew us the whole surface thereof to be very thick set with sharp points, that penetrate the skin when touched, and occasion pain, heat, and swelling; they are represented in a small part of the leaf as they appear in the microscope, by fig. 525. at A B, consisting of a rigid hollow body tapering from B, till it terminate in the most acute point imaginable, being exceedingly clear and transparent. At the bottom of this cavity lies a minute bag B, containing a limpid liquor ^a, which upon the least touch of the prickle, is squirted through the little orifice, and if it enters the skin, produces the before-mentioned mischiefs by the pungency of its salts. C D shews one of the chief fibres of the leaf, from whence the stings proceed.

The other parts of the leaf or surface of the nettle have very little considerable, but what is common to most plants, as the ruggedness, indenting, and hairiness, and other roughnesses of the surface, on the outside of the plant.

Of cowage, or cowitch.

TH E R E is a certain down of a plant, brought from the East-Indies, which grows on a kind of hairy kidney bean ^b. The pods about three inches long, resemble

^a Hook's Mic. p. 143.

^b Ibid. p. 146.

seem a French bean, and are covered with this down or hair, which is very stiff for its bigness, and causes pain, and inflammations, if rubbed on any part; and when viewed by the microscope, this down appears to be a multitude of pointed thorns exquisitely sharp.

Of the texture of the leaves of sea-weeds.

IT is a plant which grows upon the rocks under water, increasing and spreading itself into a great tuft, which is not only handsomely branched into several leaves, but its whole surface is covered over with a curious kind of carved work, consisting of a multitude of very small holes, ranged in the neatest and most delicate order; a small piece thereof is represented as it appeared in the microscope, at fig. 526.

Of flowers.

A Flower is that part of a plant which contains the organs of generation, or the parts necessary for the propagation of the kind.

It is a natural production, which precedes the fruit, and yields the grain or seed.

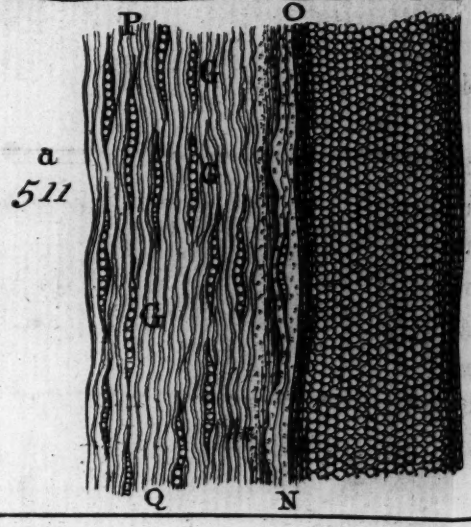
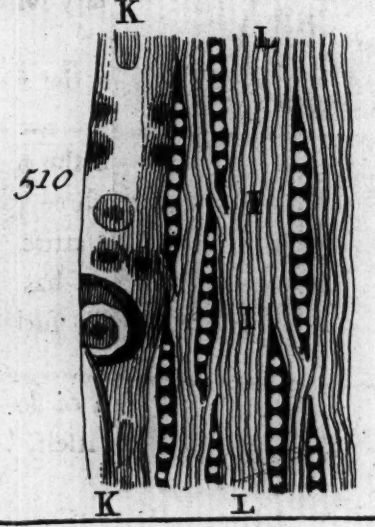
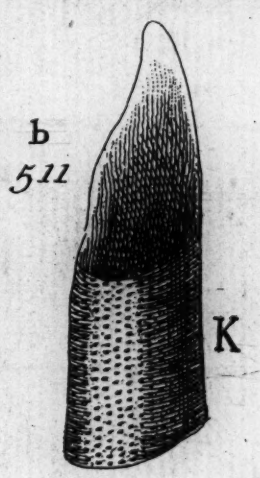
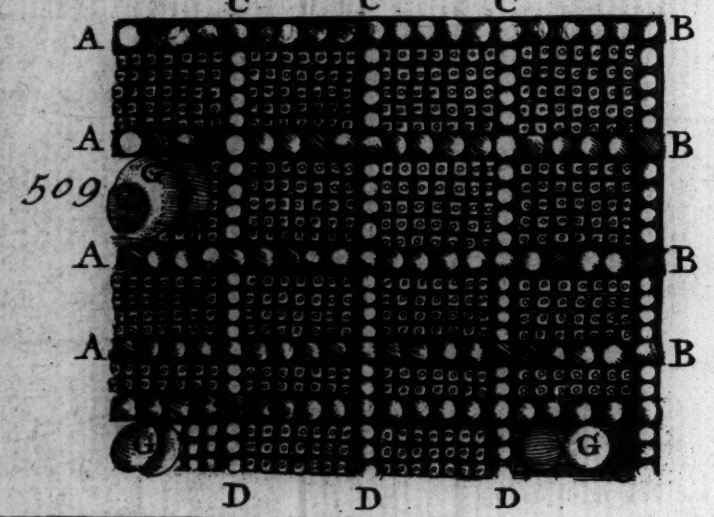
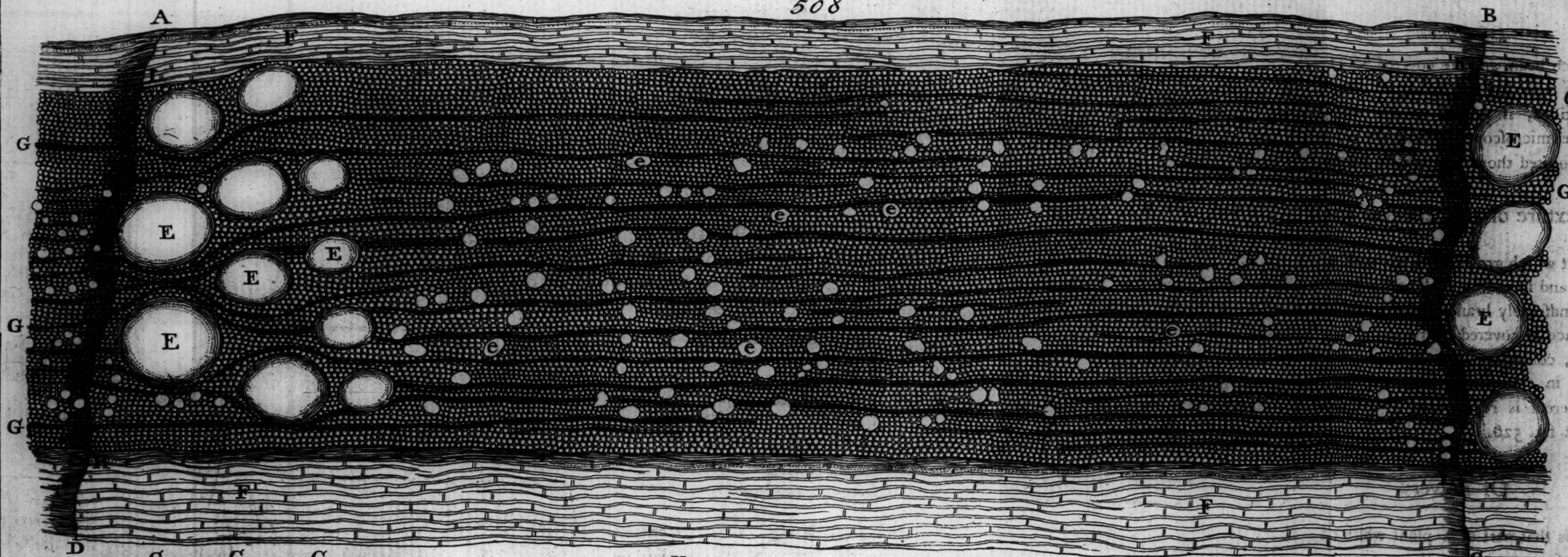
Their structure is somewhat various, though the generality, according to Dr. Grew, have these three parts entire, the empalement, the foliation, and the attire.

Mr. Ray reckons, that every perfect flower has the petala, stamina, apices, and stylus, or pistil; such as want any of these he deems imperfect flowers.

In most plants there is a perianthium, calyx, or flower cup, of a stronger consistence than the flower itself, and designed to strengthen and preserve it.

Flowers,

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Flowers, whose petala are strong (as tulips), have no calyx; carnations, whose petala are long and slender, have an empalement of one piece; and others as knap-weeds, have it consisting in several pieces, and in divers rounds, and all with a counterchangeable respect to each other, for the greater strength and security of themselves and the petala, &c. they include.

The next is the foliation, as Dr. Grew, the petala, or folia, as Mr. Ray, and others; in these, not only the admirable beauty, and luxuriant colours are observable, but also their curious foldings, in the calx before their expansion, of which Dr. Grew hath these varieties, viz. the close couch, as in roses, and several other double flowers; the concave-couch, as in blataria; flora albo, the single plait, as in pease-blossoms; the double plait, as in blew-bottles, &c. the couch and plait together, as in marigolds, daizes, &c. the rowl, as in lady bower; the spire, as in mallows; and lastly, the plait and spire together, as in convolvulus doronici folio.

As to the stamina with their apices and stylus (called the attire by Dr. Grew) they are admirable, whether we consider their colours, or their make, but especially their use, if it be as Dr. Grew, Mr. Ray, and others imagine, namely, as a male sperm, to impregnate and fructify the seed; which opinion is corroborated by the ingenious observations of Mr. Samuel Moreland, viz.

All flowers, in general, or at least the greatest part of them, are furnished with chives, tops, and pistils.

The farina, or fine mealy powder, which is at its proper season shed out of those thecæ or apices; seminiformes which grow at the top of the stamina, do in some measure perform the office of a semen masculinum, by dropping upon the outside of the uterus or vasculum feminine, and impregnate the included seed, &c. But Dr. Moreland

land was of opinion, that the seeds which come up in their proper involucria, are at first like the unimpregnated ova of animals; that this farina is a congeries of seminal plants^d, one of which must be conveyed into every ovum, before it can become prolific. That the stylus, as Mr. Ray, or the upper part of the pistillum, as Mr. Tournefort calls it, is a tube designed to convey these seminal plants into their nest in the ova; and that there is such a vast provision made thereof, because of the odds there are, whether one of so many shall ever find its way into, and through so narrow a conveyance.

For in the *corona imperialis*, where the uterus or vasculum feminine of the plant stands upon the centre of the flower, from the top of which stands the stylus; the vasculum feminine, and stylus together, representing a pistillum; round this are planted six stamina; upon the extremities of each of these are apices, so artfully fixed, that they turn every way with the least blast of wind, being in height almost exactly equal to the stylus, about which they play, and which in this plant is manifestly open at top; it is hollow all the way, and upon the top of the stylus there is a sort of tuft, consisting of pinguid villi, supposed to be placed there to catch and detain the farina, as it flies out of its thecæ; and that the rain either washes it, or the wind shakes it down the tube, till it reaches the vasculum feminine.

In the *caprifolium* or honey-suckle, there rises a stylus from the rudiments of a berry, into which it is inserted, to the top of the monopetalous flower; from the middle of which flower are sent forth several stamina, that shed their farina off the cases, upon the orifice of the stylus, which in this plant is villous or tufted, upon the same account as the former is.

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^d Phil. Transf. No. 287.

In allium or common garlick, there arises a tri-coccous uterus, or seed-vessel, in the center of which is inserted a short stylus, not reaching so high as the apices, which thus overtopping it, have the opportunity of shedding their globules the more easily into its orifice; for which reason there is no tuft on this as on the former, to insure its entrance, that being provided for by its situation just under them.

From whence we conclude, that where a fine powder is curiously prepared, carefully repositied, and shed abroad at a peculiar season, where there is a tube planted in such a manner, as to be fit to receive it, and such care in disposing this tube, that where it does not lie directly under the cases that shed the powder, it hath a peculiar apparatus at the extremity to insure its entrance, so that nothing can be more genuinely deduced from any premises, than it may from these, that this powder, or some of it, was designed to enter this tube; if these stamina had been only excretory ducts, to separate the grosser parts, and leave the juice designed for the nourishment of the seed the more reserved, what need was there to lodge these fæces in such curious repositories? they would have been conveyed any where, rather than where there was so much danger of their dropping into the seed-vessel again, as they are here. Again, the tube, over the mouth of which they are shed, and into which they enter, leads always directly into the seed-vessel; to which may be added, that the tube always begins to die, when these thecæ are emptied of their contents; if they last any longer, it is only whilst the globules which enter at their orifice, may be supposed to have finished their passage; nor can we expect a more convincing proof of these tubes being designed to convey these globules, than that they wither when there are no more globules to be conveyed.

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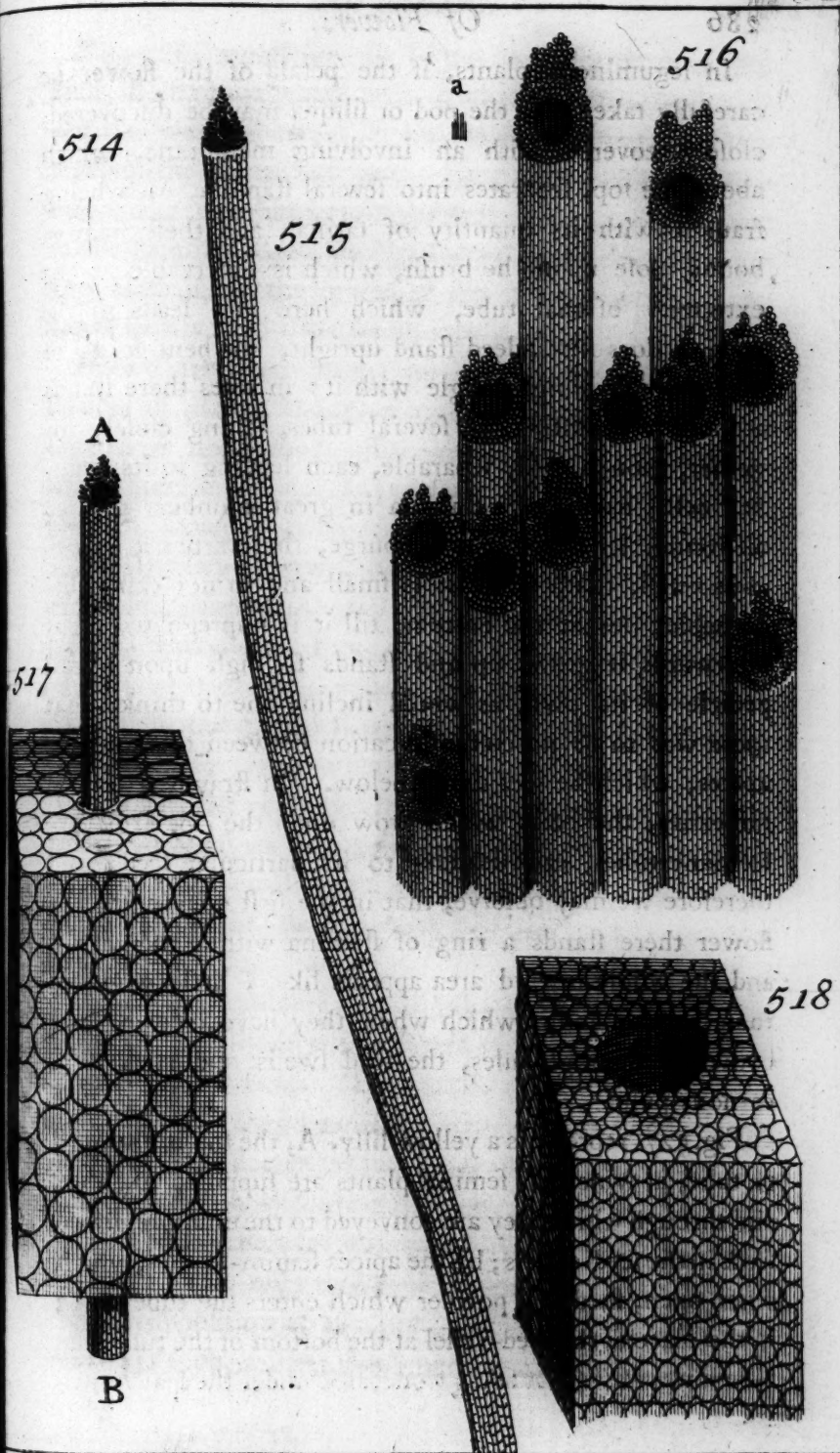
In leguminous plants, if the petala of the flower be carefully taken off, the pod or filiqua may be discovered, closely covered with an involving membrane, which about the top, separates into several stamina, each being fraught with its quantity of farina; and these stamina bound close upon the brush, which is observable at the extremity of that tube, which here also leads to the pod; it does not indeed stand upright, but bent so as to make almost a right angle with it: in roses there stands a column consisting of several tubes, clung closely together, though easily separable, each leading to its peculiar cell, having the stamina in great numbers planted all round. In tithymalus or spurge, there arises a tricoccus vessel, that, whilst it is small and so not easily discernable, lies at the bottom, till it is impregnated; but afterwards it grows up and stands so high upon a tall pedicle of its own, as would incline one to think, that there was to be no communication between this and the apices, which he sees dying below. In strawberries and raspberries, the hairs which grow upon the ripe fruit are so many tubes, each leading to its particular seed; and therefore we may observe, that in the first opening of the flower there stands a ring of stamina within the petala, and the whole inward area appears like a little wood of these hairs or pulp, which when they have received and conveyed their globules, the seed swells and rises in a carnosus pulp.

Fig. 527. represents a yellow lilly. A, the top of the pistil or tube, at which the seminal plants are supposed to enter, and through which they are conveyed to the unimpregnated seeds in the seed-vessels; b b the apices femini-formes, which when open, shed that powder which enters the tube at A; C the place of the seed-vessel at the bottom of the tube, the tube and vessel itself being concealed under the leaf in this figure.

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Fig. 528. represents the filiqua in a flower of a pea kind, E the tube which arises from the filiqua, and conveys the plants thereto; F the membraneous coat which involves the filiqua laid open: g g g g the apices, which before the membraneous tegument is laid open, appear to rise from its edges, and by the petals of the flower are kept close upon the orifice of the tube, that they may conveniently shed their farina into it.

Hence we learn from the general structure of the flowers of plants, though diversified infinite ways, that some have no sensible pistil, others no stamina, others have stamina without any apices; and what exceeds all the rest, some plants have no flowers.

Mr. Bradley observes, that at the bottom of the pistil of the lilly, there is a vessel which he calls the uterus, or womb, wherein are three ovaries filled with little eggs, or rudiments of seed, which, says he, always decay and come to nothing, unless impregnated by the farina of the same plant, or some other of the same kind.

It is this farina or dust falling out of the apices on the pistil, fecundifies the grain or fruit inclosed therein; and hence they call it the farina secundans. Thus the farina should be the male part of the plant, and the pistil the female.

The fruit is usually at the basis of the pistil, so that when the pistil falls with the rest of the flower, the fruit appears in its stead. The pistil is frequently the fruit itself, but still they have both the same situation in the center of the flower, whose leaves disposed around the little embryo, only seem destined to prepare a fine juice in their little vessels for its support. Mr. Bradley imagines their use to be only to defend the flower.

The disposition of the pistil, and the apices about it, is always such, as that the farina may fall on its orifice,

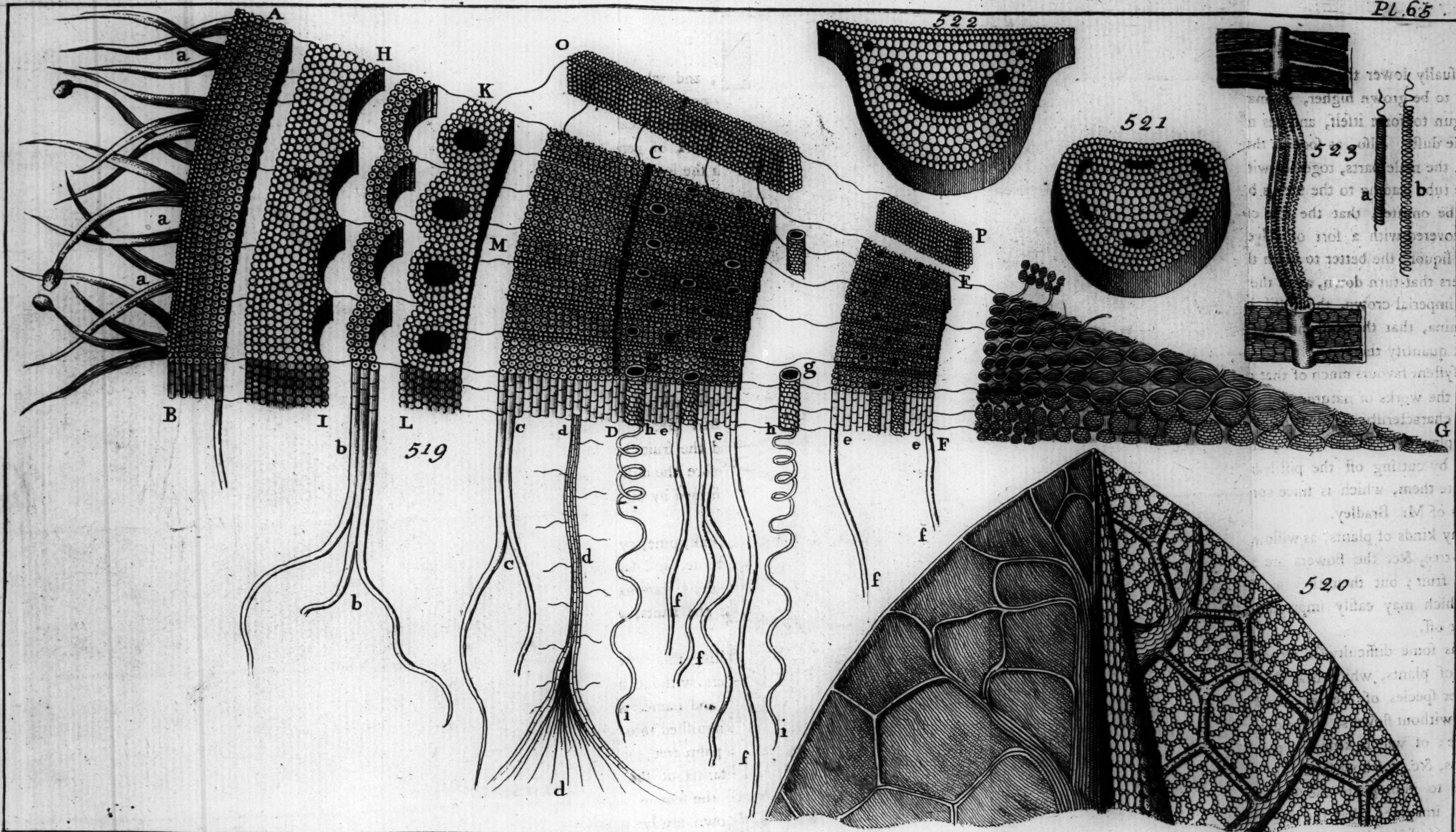
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it is usually lower than the apices; and when we observe it to be grown higher, we may conjecture the fruit has begun to form itself, and has no further occasion for the male dust. Also, as soon as the work of generation is over, the male parts, together with the leaves, fall off, and the tube leading to the uterus begins to shrink. Nor must it be omitted, that the top of the pistil is always either covered with a sort of velvet tunicle, or emits a gummy liquor, the better to catch the dust of the apices. In flowers that turn down, as in the acanthus, cyclamen, and the imperial crown, the pistil is much longer than the stamina, that the dust may fall from their apices in sufficient quantity thereon.

* This system favours much of that admirable uniformity found in the works of nature, and carries with it all the seeming characteristics of truth. Mr. Geoffroy says, that the plant is rendered barren, and the fruits become abortive, by cutting off the pistils before the dust could impregnate them, which is since confirmed by other experiments of Mr. Bradley.

In many kinds of plants, as willow, oak, pine, cypress, mulberry-tree, &c. the flowers are sterile, and separate from the fruit; but then they have their stamina and apices, which may easily impregnate the fruits, which are not far off.

There is some difficulty in reconciling this system to a species of plants, which bear flowers without fruits, and another species of the same kind and name, which bear fruits without flowers; hence distinguished into male and female; of which kind are the palm-tree, poplar, hemp, hops, &c. for how should the farina of the male here come to impregnate the seed of the female. Mr. Tournefort imagines, that the fine down always found on the fruit of these plants, may serve instead of flowers,
and



and do the office of impregnation; but Mr. Geoffroy rather takes it, that the wind doing the office of a vehicle, brings the farina of the males to the females.

For the manner wherein the farina fecundifies, Mr. Geoffroy advances two opinions, 1. That the farina being always found of a sulphurous composition, and full of subtile penetrating parts, falling on the pistil of the flowers, there resolves, and the subtilest of its parts penetrating the substance of the pistil and young fruit, excite a fermentation sufficient to open and unfold the young plant, contained in the embryo of the seed; in this hypothesis the seed is supposed to contain the plant in miniature, only wanting a proper juice to unfold its parts and make them grow.

The second opinion is, that the farina of the flower is the first germ, or bud of the new plant, and needs nothing to unfold it, and enable it to grow, but the juice it finds prepared in the embryo's of the seed.

The reader will here observe, that these two theories of vegetable generation, bear a strict analogy to those of animal generation, viz. either that the young animal is in the semen masculinum, and only needs the juice of the matrix to cherish and bring it forth, or that the animal is contained in the female ovum, and needs only the male seed to excite a fermentation.

Mr. Geoffroy takes the proper seed to be in the farina, because the best microscopes do not discover the least appearance of any bud in the little embryo's of the grains, when examined before the apices have shed their dust.

In leguminous plants, if the leaves and stamina be removed, and the pistil, or that part which becomes the pod, be viewed with the microscope, ere yet the flower be opened, the little green transparent vesiculæ, which are to become the grains, will appear in their natural

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order,

order, but still shewing nothing else but the mere coat or skin of the grain.

If the observation with the microscope be continued for several days successively, in other flowers as they advance, the vesicula will be found to swell, and by degrees to become replete with a limpid liquor; wherein when the farina comes to be shed, and the leaves of the flower to fall, we observe a little greenish speck, or globule, floating about at large. At first there is no appearance of organization in this little body; but in time, as it grows, we begin to distinguish two little leaves like two horns. The liquor insensibly diminishes as the little body grows, till at length the grain becomes quite opaque; when upon opening it, we find its cavity filled with a young plant in miniature, consisting of a plumula, radicle, and lobes.

The tops or apices sometimes stand erect above their chives or stamina, as those in lark-heel, but generally hang a little down by the middle like a kidney bean, as in mallows; they have for the most part a double cleft, though it is in some single, from which they disburse their powders which start out, and stands upon the lips of the cleft, as at fig. 529. which represents one of the apices of the flower of St. John's wort magnified.

The particles of these powders although like meal or dust, yet if viewed through a microscope, they have all of them very curious and regular forms. In dog's-mercury and borage they are extremely small, but in mallows fairly visible to the naked eye. In some flowers these powders are yellow, as in dog's-mercury, goat's rue, &c. and in some of other colours, but in most they are white; those of yellow henbane are very elegant, being to the naked eye as white as snow, and in the microscope as transparent as crystal.

The tops or apices which contain the farina, are for the most part either white or yellow, sometimes blue, but never red. Whatever colours the flowers be of, they differ in position, sometimes standing double upon one chive, as in toad-flax, snap-dragon, &c. In some they are fastned to their stamina at their middle, as in Spanish broom, hyssop, scabious, behen, &c. in some erect, as in clematis, austriaca, ladies looking-glass, rape crow-foot, &c. coded arsmat hath no chives, but stand upon a large base.

Their number are also different, in great celandine, rose, rape-crow-foot they are numerous; in great plantain, and some other herbs, much more conspicuous than the foliage itself. In germander chickweed, they are always two, and no more; in some they follow the number of the leaves, especially in the number five; as in blattaria, black henbane, &c. In stichwort and lychnis sylvestris they are ten, just double to the number of leaves.

Their shape is different, and always very elegant, with great variety. In borage, like the point of a spear; in blattaria, like an horse-shoe; in clematis like a spatula, wherewith Apothecaries make their mixtures: in mallow like a head-roll; in hyssop they have one cleft before, in blattaria one round about; in water betony one at the top; in scabious they have a double cleft, one on each side.

In colocynthis the farina is not contained in several thæcæ or apices standing upon chives, but is all of one entire part, like a thick column in the midst of the flower, having several little ridges or furrows winding from the top to the bottom round about, in the middle of each of which runs a line, where the skin, after some time, opens into two lips, and presents the globular particles contained in the hollow of every ridge.

But where the seeds are contained in the apices, a stilus or little column stands upon the top of the true seed-case, which is also regularly and variously figured. In bindweed it hath a round head like that of a great pin. In the common bell, St. Johnwort, &c. it is divided into three parts. In geranium into five; in asarum into six; sometimes the head is smooth, and in others it is beset with little thorns, as in hyoscyamus.

The pistil is a little upright part in the middle of the calx, or the leaves of flowers, called also the style.

It is an essential part of a flower, and the principal female organ of generation, it being in this that the seeds or young plants are formed. It arises from the pedicle of the flower, or the center of the calx, and at length becomes the young fruit, which is sometimes hid in the calx, and sometimes quite out.

Its figure is very different in different flowers; in some it is a little stalk, which enlarges at the two ends, in others a mere stamen or thread, sometimes it is round, sometimes square, triangular, oval, &c.

Almost all pistils are furnished at top, either with fine hairs, or little filaments disposed in plumes, or are beset with little vesicles full of a glutinous juice.

Some flowers have several pistils, or rather the pistils terminate in several branches, which have their rise from as many young fruits, or as many capsulæ containing seeds.

Whatever form the pistils are in, they have certain apertures at their tops, or clefts, continued their whole length, to the base or embryo of the fruit.

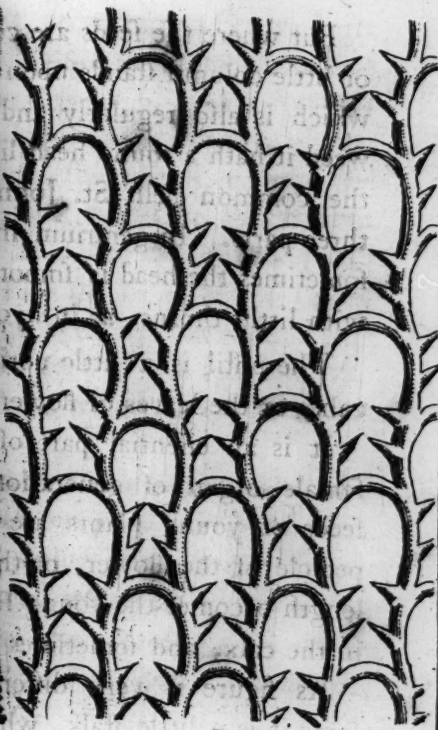
The seed vessels consists sometimes of two, and for the most part of three pieces; for which reason they are called suits, as at a b c d, fig. 527.

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...the following ...

The outer part of each suit, according to Grew, is its floret, whose body or tube is divided at the top (like that of a cowslip) into five leaves as at b, which forms a flower in miniature, and is all the flower in many plants, as mugwort, tanfye, &c. Upon the expansion of the floret, the next part c, of the suit, begins to appear from within its tube, which may be called the sheath (with respect to that within it). This sheath in a short time divides at top, through which aperture the blade d displays itself. This is the third part of the suit, and terminates in a forked point, about which appear little globules.

In some flowers every one of the before-mentioned florets is encompassed with an hedge of hairs, and every hair branched on both sides, almost like a sprig of fir, as at c d in golden rod, fig. 530. which shews one of the suits thereof as it appeared in the microscope, in which at e is the little column or blade that contains the farina, which is also seen by itself at F.

The base of the floret is generally cylindrical, but sometimes square, as in French marigold, at a, fig. 531. and the leaves thereof, which for the most part are smooth, in the same flower are all over hairy. The middlemost of the three parts or sheath b, is usually fastned to the top, or else at the bottom of the floret, and is rather indented than parted into leaves: the surface seldom plain or even, but wrought into five ridges and as many gutters, running almost parallel from top to bottom.

The inmost part or blade runs through the hollow of the two former as at a, fig. 531. and is fastned with the floret to the convex of the seed case; the head and sides of this part is always beset round about with globulets. In some growing close to the blade, as in common marigold; and in the French marigold, as at fig. 532. and others, upon little slender stalks. These, as the blade

springs up from within the sheath, are rubbed off and stands like a powder upon them both. In some, as in chicory, they seem to grow within-side the sheath, as will appear if it be split * with a small pin, as also in knap-weed they are very numerous.

The head of the blade is always divided into two, and sometimes into three parts, as in chicory, fig. 533. which gradually curl outwards after the manner of scorpion grafs.

This description agrees principally to the corimbiferous kind, as tanfy, camomile, &c. but in scorzonera, chicory, fig. 533. hawk-weed, mouse-ear, and all the intibous kind, with many more. The pistil is separated from the foliature, so as to stand alone therein, every leaf a b c of the flower having a pistil of its own; for which reason the base of each leaf is formed into a little tube a, fig. 533. that incloses the pistil, which commonly consists of a sheath and blade e; the leaf itself answering to the floret in other flowers. The blade (or rather stamina) is seen drawn out of its sheath at f g of the same figure, and at g the head of the blade is opened into three parts, which are full of those globular particles before-mentioned.

The time in which the flower is generated, is hardly any where, if at all taken notice of among so many observers of plants. It is therefore to be remarked, that all the parts of the flower in all flowers, are perfectly finished long before they appear in sight, usually three or four months, and in some six. And that in perenial plants, those flowers which appear in any one year are not formed in that, but were actually in being and intire in all their parts the year before. The flower of mezeron, which opens in January, is intirely formed about the middle of August in the foregoing year; at which time, if the green leaves of the bud be carefully removed, the leaves of the flower

* Grew Ana. Plants, p. 170.

flower and seed-like attire, encompassing the seed-case, may be distinctly seen when placed before the microscope.

In order to observe the mealy powder or farina, let it be gathered in the midst of a sun-shiny day when all the dew is off, shake, or else gently brush it off with a soft hair-pencil upon a clean piece of white paper; then breathe upon a single talc, and instantly apply it to the farina, which will adhere to it. If too great a quantity of powder sticks to the talc, blow a little of it gently off, if not enough breathe on it again, and touch the farina with it as before, then fix it in a slider as before directed.

But I would here advise the curious not to neglect an examination of the little cells that contain the farina, and also of the pistils and uteri, and other parts of generation of the flowers.

Fig. 534. represents the flower of St. Johnswort a little magnified, in which may be seen the stamina and their apices surrounding the seed-case, fig. 529. is one of the apices more magnified.

Fig. 530. represents one suit of golden rod flower, consisting of a seed-case A, and a stamina e, one of which is seen by itself at F.

Fig. 531. shews one of the suits of French marigold, or flos Africanus magnified, of which there are about twelve in one flower, each consisting of three pieces, the middlemost of which is seen alone at fig. 532.

Fig. 535. represents one suit of chrysanthemum-creet, consisting also of three pieces, of which there are about eighty in one flower.

Fig. 536. exhibits one suit of knapweed magnified, consisting of three pieces, a b is the seed-case, at the bottom of every suit.

Fig. 537. is a microscopic representation of one of the suits of marigold, of which there are about forty in one flower.

Fig. 533. represents the pistil and blade, proper to each leaf in the flower of chicory.

Fig. 538. represents one of the flowers in the bud of mezeron perfectly formed in all its parts the year before it appears, but differs in shape as a foetus doth when newly formed.

Fig. 539. shews the same flower cut open, wherein may be seen the spermatic thæcæ and the uterus.

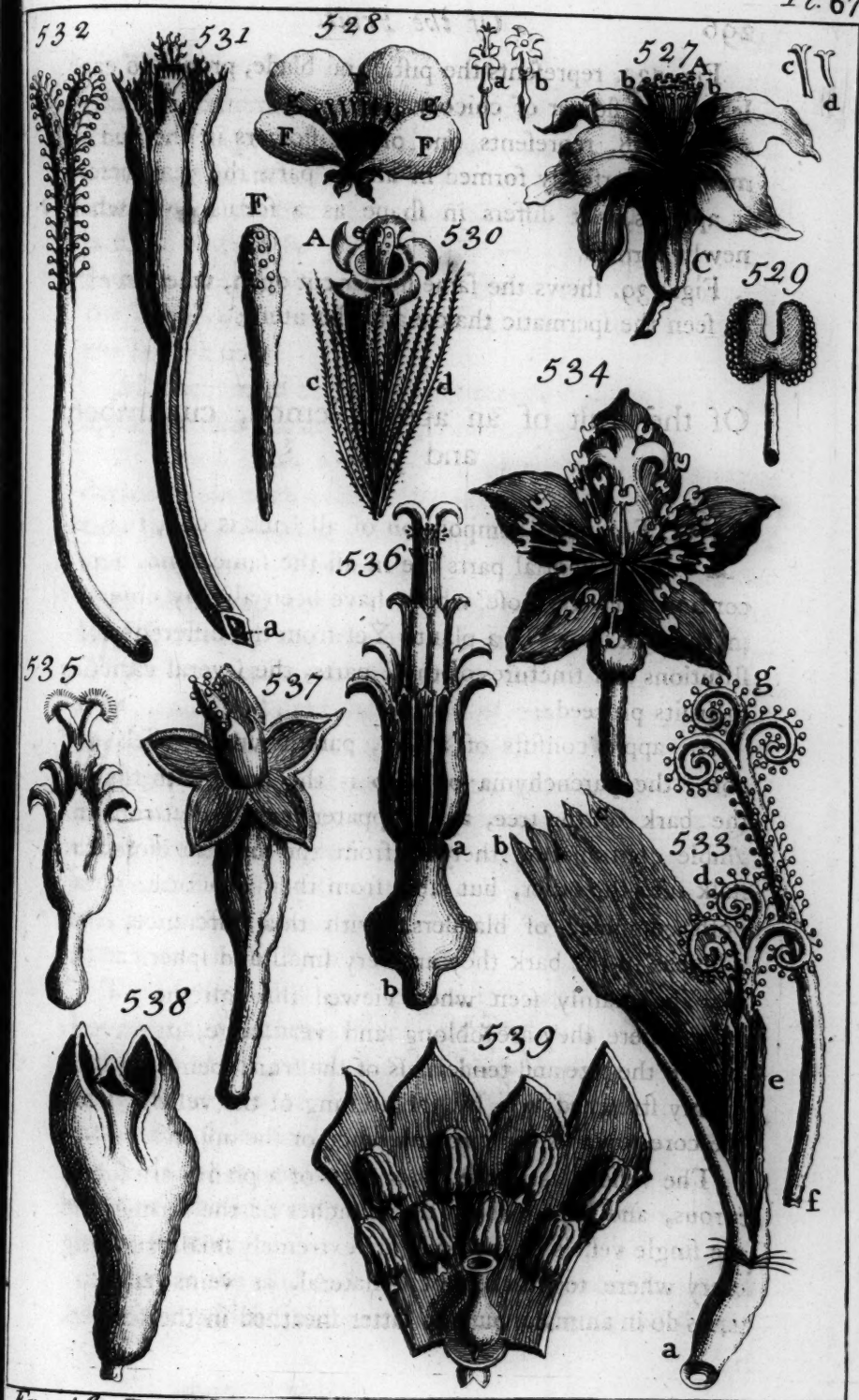
Of the fruit of an apple, lemon, cucumber, and pear.

THE general composition of all fruit is one, that is, their essential parts are in all the same, and but a continuation of those which have been already observed in the other parts of a plant. Yet from the different constitutions and tinctures of those parts, the several varieties in fruits proceed.

An apple consists of a skin, parenchyma, vessels and core; the parenchyma or pulp is the same with that of the bark of the tree, as is apparent not only from the visible continuation thereof, from the one through the stalk into the other, but also from their structure, being both composed of bladders, with this difference, that whereas in the bark they are very small and spherical (as may be plainly seen when viewed through the microscope) here they are oblong and very large, in proportion to the size and tenderness of the fruit, being all uniformly stretched out by the arching of the vessels, from the core towards the circumference of the apple.

The vessels, as in the other parts of a plant, are succiferous, and for air, both the branches of the former and the single vessels of the latter are extremely small, running every where together; not collateral, as veins and arteries do in animals, but the latter sheathed in the former.

They



the whole of the system is divided into twenty principal branches, and each of these is further subdivided into smaller branches, the number of which varies according to the nature of the system. The system is also divided into two main parts, the first of which is the system of the mind, and the second is the system of the body. The system of the mind is divided into three main parts, the first of which is the system of the intellect, the second is the system of the emotions, and the third is the system of the will. The system of the body is divided into four main parts, the first of which is the system of the senses, the second is the system of the muscles, the third is the system of the bones, and the fourth is the system of the organs. The system of the intellect is divided into two main parts, the first of which is the system of the understanding, and the second is the system of the reason. The system of the emotions is divided into two main parts, the first of which is the system of the passions, and the second is the system of the affections. The system of the will is divided into two main parts, the first of which is the system of the desires, and the second is the system of the volitions. The system of the senses is divided into five main parts, the first of which is the system of the sight, the second is the system of the hearing, the third is the system of the smell, the fourth is the system of the taste, and the fifth is the system of the touch. The system of the muscles is divided into two main parts, the first of which is the system of the voluntary muscles, and the second is the system of the involuntary muscles. The system of the bones is divided into two main parts, the first of which is the system of the long bones, and the second is the system of the short bones. The system of the organs is divided into two main parts, the first of which is the system of the solid organs, and the second is the system of the hollow organs.

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They are distributed into twenty principal branches, the ten outermost a little within the apple, are diverted from a straight line into so many arches; from which a few small branches are without any order dispersed thro' the apple; the five middlemost and the five inmost run in a strait line as far as the core, and are there distributed into as many lesser arches, the former at the outer and the latter at the inner angles of the core, upon which last the seeds hang.

All these main branches meet together at the top of the apple, where originally they ran into the flower.

A lemon hath a three-fold parenchyma, seemingly derived from each other; the texture upon every derivation being somewhat altered, by being made more close and elaborate. The outmost called the rind, hath the most open and coarsest texture, being composed of the largest threads, and these wove up into larger bladders. Those little cells which contain the essential oil of the fruit, and stand near the surface of the rind, are some of the same bladders, but more dilated.

From this outmost parenchyma, nine or ten insertions are produced, betwixt as many portions of the pulpy part towards the center, where they all unite into one body, answerable to the pith in the trunk or root of the tree; and are a conspicuous demonstration of the communication between the bark and pith.

Throughout this parenchyma the vessels are dispersed, but the chief branches stand on the inner edge of the pith, just at the extremities of every lamellæ from those branches at the edge of the pith; other little and very short ones shoot into the pulp of the fruit, upon which the seeds are appendant. In the center of the pith are eight or nine in a ring, which run through the fruit up to the flower.

Between the rind and pith, and those several lamelated insertions which join them together, stands the second
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sort of parenchyma, being closer and finer, and divided by the lamels into several distinct bodies, every one of them being an entire bag; in every one of which the parenchyma is contained; which is also a cluster of other lesser bags, all disjoined from one another, each having their distinct stalks of several lengths, by which they are all fastned to the utmost side of the great bag wherein they are contained. Within these lesser bags also the microscope can shew many hundreds of bladders, consisting of extremely fine threads, as it were wove together into that figure; and within these bladders lies the acid juice of the lemon.

A cucumber hath also a three-fold parenchyma, the outermost is derived from the bark, which being exposed for some time to dry, and then transversly cut with a razor; not only the bladders but also the threads whereof the bladders consist, are plainly visible when viewed thro' the microscope.

Throughout this parenchyma are dispersed the sap vessels, in ten or twelve very large branches, each of which embosoms another of air vessels.

The middle parenchyma is derived from the pith, and divided into three triangular columns, within which are a distinct sort of sap vessels, whence several small and short fibres shoot into the inmost parenchyma, whereupon the seeds do hang.

The inmost parenchyma wherein the seeds do lie (and which answers to the pulp of a lemon) seems to be produced from the seed-fibres, by three insertions from the columns, and as many from the outmost parenchyma, and these reinserted; it is divided into six triangular bodies, and every triangle into three ovals.

A pear, besides the skin, consists of a two-fold parenchyma of vessels, tartareous knots, or grains, and a core; the skin when viewed in the microscope, appears to be lined with a great number of these tartareous grains, which

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are also dispersed round about the fruit, for about the thickness of the third of an inch, as will appear on applying a transverse slice of a pear to the microscope.

The outer parenchyma is of the same original and general structure as in an apple, but the bladders not altogether so long with respect to their breadth.

The bladders here have also a different position from that they have in an apple, being in that all stretched out towards one common center, which is that of the apple itself. But here they every where bear a respect to the said tartareous grains, every grain being the center of a certain number of bladders.

Throughout this parenchyma, the vessels for sap and air are likewise dispersed into fifteen principal branches. The five utmost make as many arches, but commonly not so deep as in an apple; from these some small fibres are dispersed throughout the parenchyma. The ten inner branches proceeding to the seed, and from thence with the other five to the flower.

Next the core stands the inner parenchyma, consisting of small roundish bladders, answerable to that of the pith, from which it seems to be derived.

Between this and the outer parenchyma, the said tartareous grains begin (first) to stand nearer together, to grow bigger, and of a more unequal surface; and by degrees to unite into a body, in some pears, and especially towards the core, they are almost as hard as a plumb-stone.

On cutting a pear lengthwise, through its center, these tartareous grains will be apparent.

At the bottom of the core in most pears, and a little below the center of the fruit, is a kind of umbelical knot; from whence extends a straight channel, which opens at the middle of the core or stool of the flower, scarce wide enough to admit the smallest pin.

Of

Of a plumb, and some other fruits of the same kind.

A Plumb consists of a parenchyma, the two general kind of vessels, and a stone; and in proportion to the bulk of the fruit, hath more vessels than an apple or pear. Also in plumbs, all these vessels are braced together into one uniform piece of net-work, every where terminating at an equal distance from the circumference, the skin is fibrous and tough.

The stone is composed of two, or rather three distinct parts, one of them the lining, taking its rise from the parenchyma, which the seed branch brings along with it, through the channel in the side, and at last into the hollow of the stone, and is there spread all over it.

The foundation or ground of the outer and more bulky part of the stone, is the inner part of the parenchyma, upon which the tartareous parts of the sap are continually precipitated, and thereby petrified, as appears on comparing the several ages of the same fruit together; on the surface of many stones, some of the said tartareous parts appear in distinct grains.

An apricock is of the plumb kind, but some things are herein better observed, as first the position of the bladders of the parenchyma; for the tartareous parts of the sap, not being here dispersed in little grains, throughout the fruit as in a pear, but are all thrown off into the stone; therefore the bladders all radiate exactly to the center of the stone, conveying thereto the feculent sap, in so many little streams. This is best seen when the fruit is full ripe.

The gradual transmutation of the inner part of the parenchyma into a stone, is also more apparent in this fruit,

fruit, and so are the three coats which serve for the generation of the seed; being now all very distinct and remarkable.

A peach hath a much bigger stone, and therefore when full ripe, it hath a more defecated or better refined juice; the reason why the stone is so great, is because the vessels run so numerously through the body of it; and so cause a more copious perspiration of the lees therein.

A cherry is likewise nearly related to a plumb, but the bracement or reticulation of the vessels, is here carried on farther, so as to be all round about contiguous to the skin.

A walnut is a nuciprune, or between a plumb and a nut, for the rind answers to the pulp, and the shell, as the stone, is also lined; but the seed-vessels, which in a plumb run through a channel, made on purpose in the stone, do here enter as in a nut, at the center of the shell; by which means they are invested with a more fair parenchyma.

Of the grape.

A Grape is as it were a plumb with two stones, for their thickness are as hard as any other. The principal fibres run directly between the stones; and the smaller fibres, and make only one single net; near the circumference they all meet together at the top of the grape. Many lignous fibres are also mixed with the skin itself, whereby it becomes very thick and tough.

The parenchyma, or pulp of a grape seems to be derived from the pith, at least as far as the reticulation of the fibres.

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The anatomical preparation of vegetables.

THOSE leaves of plants are only fit for this purpose, whose internal structure is composed of woody fibres, and are of a pretty good thickness, as the leaves of oranges, lemons, jessamin, bays, roses, cherries, apri-cocks, peaches, plumbs, apples, pears, poplars, pines, oaks, ivy, &c.

There are several other that have no woody fibres or veins, but these dissolve without separating, as those of vines, and lime-trees.

The leaves are to be gathered ^f in June, or July, when they are full grown, and have not been damaged by worms, or caterpillars; put them into an earthen pot or large glass, with a good deal of rain-water, the pot or glass being kept uncovered with water, and as it evaporates a fresh quantity must be poured in. In about a month's time, some of the leaves will begin to putrify, but the others must be kept two months longer. When the two external membranes begin to separate, and the green substance of the leaf to grow liquid, then it is time to perform the operation. The leaf is to be put into a white flat earthen plate or dish, filled with clear water; then upon gently squeezing it with the finger, it will open on one side, and the green substance will run out; immediately on that the two outer membranes must be stripped off, chiefly in the middle, and along the nerves, where they adhere closely. If there be once an opening, they will go off very easily; the skeleton that remains between, is afterwards washed in clean water, and kept between the leaves of a book.

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^f Phil. Transf. No. 416.

The method of preparing fruits, as apples, plumbs, cherries, peaches, and the like, is as follows :

The finest and largest pears, that are soft and not stony, are fittest for this purpose ; first pare them nicely, without squeezing them, taking care not to hurt the stalk or crown ; then put them into a pot of rain or fresh spring water, cover it, and let them boil gently, till they become thoroughly soft ; then take them out, and put them into a basin of cold water, then take out one of them, and holding it by the stalk with one hand, and with one finger and the thumb of the other hand rub the pulp gently off, beginning near the stalk, and rubbing equally towards the apex ; and you will easily see in the water how the pulp separates from the fibres, which being tenderest near the extremities, there the greatest care must be taken. No instrument is of use in this operation, except last of all a penknife, to separate the pulp sticking to the core. In order to see how the operation advances, sling away the muddy water from time to time, and pour on clean. All being separated, the skeleton is to be preserved in spirits of wine ; the same is to be observed with apples, plumbs, peaches, and the like.

Carrots, and other roots, that have woody fibres, must be boiled without paring, till they grow soft, and the pulp comes off ; not only several sorts of roots, but likewise the barks of several trees, may be reduced into skeletons, presenting rare and curious views of vegetables.

To preserve the specimens of plants.

Prepare two iron plates as large as the specimens you intend to preserve, let them be pretty thick, and very smooth on each side, with holes for screws at each corner ;

304 *Of Charcoal, or burnt Vegetables.*

corner; then take your flowers, leaves, &c. when full ripe, and of their true colour, spread them on a brown paper, with the leaves as distinct as you can; if the flowers are large, more paper must be laid under them; and if thick you may pare away half thereof, as also of the stalk so as to lie flat; then put these between the iron plates, screw them fast, and set them in an oven for two hours; after which take out the flowers, and with a brush dipped in equal quantities of aqua fortis, and aqua vitæ, or brandy, pass over the leaves and flowers; then lay them to dry on fresh brown paper, and take the quantity of a walnut of gum dragon, which in less than twenty-four hours will be dissolved in a pint of water, and with a brush rub the back-sides of the leaves and flowers to make them stick; then lay them into your paper-book, and they will always look fresh ^z.

Of charcoal, or burnt vegetables.

CHarcoal, or a vegetable burnt black, affords an object no less pleasant than instructive; for if a small piece of charcoal be suddenly broke, it will appear to have a very smooth surface, but if examined by the microscope, abundance of pores are discoverable in many kinds of wood, ranged round the pith both in a circular and a radiant order; and most of these so exceeding small, and so close to each other, that but a very little space is left between them to be filled with a solid body. These pores, or rather tubes, are so extremely small, that in a line of them, one eighteenth part of an inch long, Mr. Hook reckoned no less than an hundred and fifty, therefore in a line an inch long were no less than 2700 pores, and

^z Phil. Transf. No. 227.

and in a circular area, or of a stick of an inch diameter, are contained 5,725,350 pores or minute tubes^b, a number that to some perhaps may seem incredible, were they not left to the judgment of their own eyes as to the truth thereof. In cocus, black and green ebony, lignum vitæ, &c. these perforations are abundantly smaller than those of soft light wood; so prodigiously curious are the contrivances, pipes or sluices, through which the juice of vegetables are conveyed.

To prepare or make charcoal of any kind of wood, in order to examine it with the microscope.

THE body to be charred or coaled may be put into a crucible, a piece of a musket barrel, a pot, or any other vessel, that will endure to be made red-hot in the fire without breaking; cover it over with sand, so that no part of it be exposed to the open air. Then set it into a good fire, and keep it there till the sand has continued hot, for a quarter, half, an hour, or two, more or less, according to the nature and bigness of the body. Then take it out of the fire, and let it lie till the sand be very near cold. The wood may be taken out of the sand well charred, and cleared of all its watery parts.

Of the texture of cork.

IF an exceeding thin slice of cork be cut off with a very sharp penknife, or razor, and applied to the microscope, in an ivory slider, or held between the nippers,

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^b Hook's Mic. p. 101.

it will appear to be all perforated and porous; having but a little solid substance in proportion to the empty cavity, as is manifest on a sight of fig. 540. These pores are not very deep, but consist of many little cells, separated out of one continued long pore, by certain diaphragms^l, visible in fig. B, which represents them split the long ways: hence the microscope informs us, that the lightness of cork proceeds from its being a very small quantity of a solid body, extended into exceeding large dimensions, and also why it is a body so very unapt to suck in water, and consequently to preserve itself floating on the top thereof, though left on it never so long, and why it is able to confine air in a bottle tho' considerably condensed, and pressing very strongly to procure a passage without admitting the least bubble to pass through its substance. As to the first, the microscope hath informed us that the substance of cork is filled with air, and that this air is perfectly inclosed in little boxes or cells distinct from each other: this therefore makes it very plain, that neither water nor any other air can easily insinuate itself into them, their being already within them an intus existens^k; for this reason pieces of cork are good floats for nets and stopples for vials, &c. and is capable of being compressed into a twentieth part of its usual dimensions, and to restore itself to its former state by means of the included air in the before-observed constituent cells or bladders. Mr. Hook told several lines of these pores, and found that there were generally about sixty placed endways in a line of the one eighteenth part of an inch long: whence there must be 1160 in the length of an inch, and in a square inch 1166400; therefore a cubic inch must contain 1259712000, a thing almost incredible, did not the microscope assure us of it by ocular demonstration. If you cut off a piece from a board of cork transversely to the flat of it, you will as it

were

Hook's Mic. p. 113.

^k Ibid. p. 113.

were split the pores, which will appear just as they are represented at fig. B, but if a very thin piece be cut off parallel to the plane of it, the pores of it will be transversely divided, and will appear as expressed in fig. A.

Of a plant growing on the blighted, or yellow specks of damask-rose leaves, bramble leaves, &c.

IT is observable that in the months of June, July, August, and September, that many of the green leaves of roses begin to dry and grow yellow, but especially the leaves of the old shrubs of damask roses, are all spotted with yellow stains, and the under-sides just against them have little yellow hillocks of a gummy substance, and several of them have small black spots in the midst of those yellow ones. Upon examining these with the microscope, multitudes of little black bodies like seed-cods were perceived to spring out of several small yellow knobs, and to be fastned to these knobs by a small straw-coloured and transparent stem, many of those hillocks were bare as if those bodies lay yet concealed, at at G, fig. 541. In others they were just springing out, as at A; in others, as at B, they were just out, with very little or no stalk; in others, as at C, the stalks plainly appear; in others, and at D, those stems were grown bigger and larger; and in others, as E F, &c. those stems and cods were grown a great deal bigger, and the stalks more bulky about the root, and very much tapered towards the top: as they increased in bulk they began to turn their tops towards their roots, in the same manner as that of moss is observed to do. The whole square of this figure represents a small part of a rose-leaf no bigger than the letter H.

308 *Of Mouldness arising from Putrefaction.*

These kind of vegetable sprouts are to be found on several kinds of rose-leaves, and on the leaves of divers sorts of briars, and on bramble leaves in such clusters, that three or four hundred of them make a conspicuous black spot or scab on the backside of the leaf.

Of mouldiness, or the principals of vegetation arising from putrefaction.

MR. Leeuwenhoek observes, that mouldiness on skin, flesh, or other things, shoots up first with a streight transparent stalk, in which a globular substance rises that commonly settles at the top of the stalk, and is followed by another globule driving out the first either on the side or at the top, and that again is succeeded by a third, &c. all which form on the stalk one great knob, much thicker than the stalk itself; and this large knob bursting asunder represents a kind of blossoms with leaves¹.

The blue, white, and several kinds of hairy mouldy spots that are observable on divers kinds of putrefied bodies, whether animal or vegetable substances, such as the skin, raw or dressed flesh, blood, humours, milk, cheese, &c. or rotten sappy wood, herbs, leaves, barks, roots, &c. are a kind of small but variously figured mushrooms; a specimen of which is represented at fig. 542. which is nothing else but the microscopic appearance of a small white spot of hairy mould found upon the covers of a book that was bound in sheep's skin. These spots appeared through the microscope to be a very pretty shaped vegetative body, which shot out multitudes of long and slender cylindrical stalks, not exactly streight, but bent with the weight of a round white knob growing upon the top

¹ Phil. Trans. No. 94.

top of each as at A A A; others a little oblong as at B, others a little broken as at C, and others that were burst asunder forming a kind of blossoms with leaves, as at D.

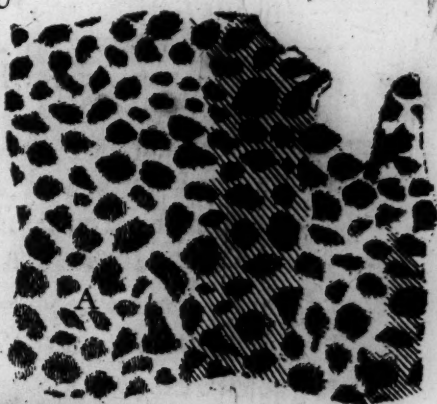
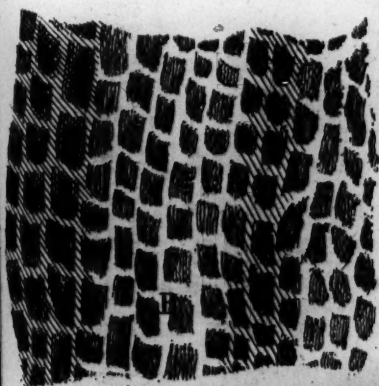
Of moss, &c.

MOSS is a plant no less worthy a microscopic consideration than the most elegant plant that grows, and for its shape and beauty may be compared with any other. It has a root almost like a seedy parsnip, fig. 543. furnished with small strings and suckers, all of them being as curiously branched as the roots of much bigger vegetables; from this springs the stem or body of the plant, which is finely creased or fluted; on the sides of this are close and thickly set a multitude of well shaped leaves, some of them of a roundish, others of a longer shape; all the surface on each side the leaf is curiously covered with a multitude of little oblong transparent bodies, as at D, fig. 546. From the tops of the leaves proceeds a transparent hair or thorn; the stem shoots out into a long round stalk, which on cutting is found to be hollow without any knot or stop, from its bottom where the leaves encompass it, to the top on which grows a large seed-case A, covered with a thin and more whitish skin B, fig. 544. terminated in a long thorny top, which at first covers all the case, and by degrees, as that swells, the skin cleaves, and at last falls off together with its thorny top, leaving the seed-case to ripen, and scatter its seed, at a place underneath this cap B, which before the seed is ripe appears like a fluted metal button, without any hole in the middle; but, as it ripens, the button grows bigger, and a hole appears in the middle of it E, fig. 545. out of which, in all probability, the seed falls; for as it ripens by the provision of nature that end of this

case turns downwards. On opening several of these dry red cases F, they were found to be quite hollow; whereas when they were cut asunder with a sharp penknife when green, in the middle of this great case was found another small round case, the interstices between the two cases being filled with multitudes of stringy fibres which seemed to suspend the lesser case in the middle of the other, in which without doubt the seeds were contained; it grows on the rotten parts of stone, bricks, wood, bones, leather, &c.

This small vegetable is wanting in nothing of the perfections of the most conspicuous vegetables of the world, and deserves to be ranged in as high a state; for we do not know but that all the contrivances and mechanism requisite to a perfect vegetable, are crowded into exceedingly less room than this of moss; for that plant already described, which grows on rose-leaves, is so exceeding small that near a thousand of them would hardly make the bigness of one single plant of moss; and by comparing the bulk of the latter to that of the biggest vegetable (some trees being, as we are informed, near twenty foot in diameter in Guinea and Brazil) whereas the body or stem of moss is generally not above one sixtieth part of an inch, we shall find that the bulk of one will exceed that of the other, no less than 2985,984,000,000; and supposing the production of the rose-leaf to be a plant, those Indian plants will exceed it a thousand times the former number, so prodigiously various are the works of the Creator, and so all-sufficient is he in his performance of things which to man would seem impossible.

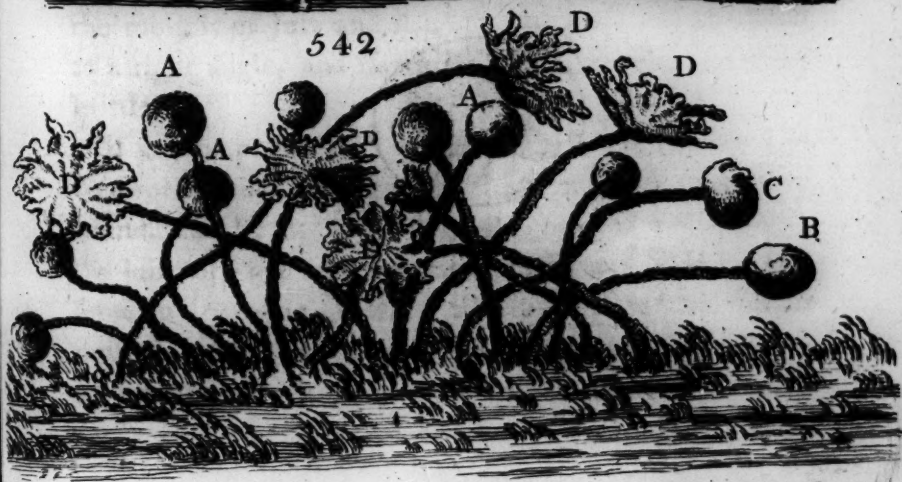
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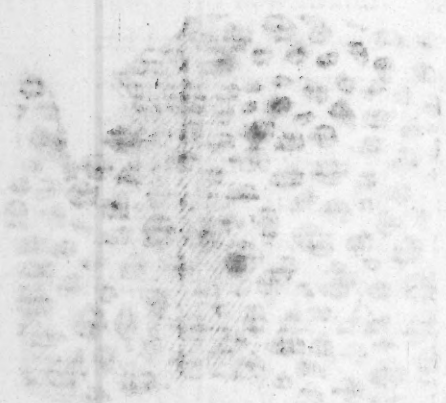


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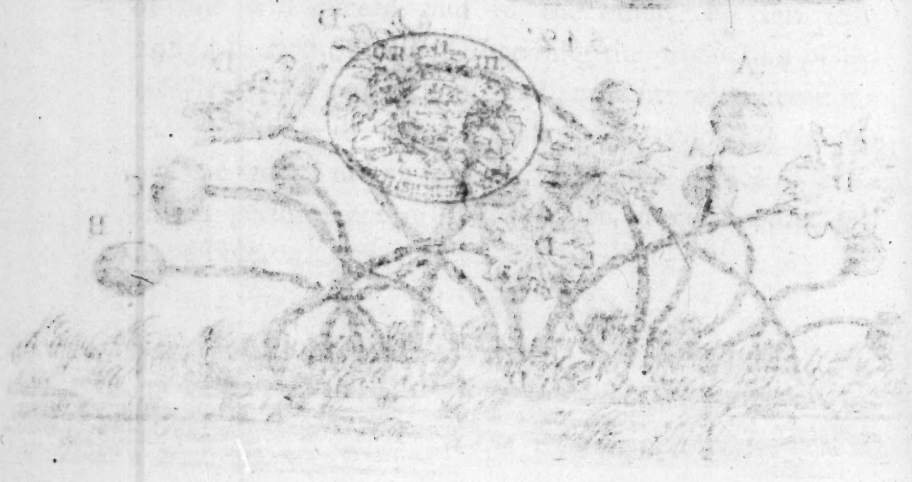


542





Very faint, illegible text, possibly a list or a table of data, located to the right of the circular diagram.



Of sponge.

THE microscope hath shewn us, that sponge is composed of an infinite number of small and short fibres, curiously joined together in the form of a net, as appears by fig. 547. which represents a piece of sponge as it appeared before the microscope, wherein may be seen the joints which for the most part are where only three fibres meet together, the length of each between the joints is very irregular, the distance between some two joints being ten or twelve times more than between others. The meshes likewise of this reticulated body are also various, some bilateral, others trilateral, and quadrilateral figures, &c.

Of the beard of a wild oat.

THE beard of a wild oat is a body of a very curious structure; it grows out of the side of the inner husk that covers the grain of a wild oat. Its whole length when extended does not exceed an inch and a half. When the grain is ripe and very dry, which is usually in the months of July and August, the beard is bent almost to a right angle, and its under part is wreathed and very brittle.

If you take one of these grains and wet the beard in water, the small bended top will presently turn and move round, -and by degrees, if it be continued wet enough, the joint or knee will streighten itself, and if it be suffered to dry again, it will gradually bend into its former posture. Its appearance in the microscope is represented by fig. 548. which shews part of the beard at the knee or

bend. Its whole surface is adorned with little channels and interjacent, ridges, which run the whole length of the beard, and are streight where the beard is not twisted, and wreathed where it is, being thickly set with small bristles; in the wreathed part was two very conspicuous channels, which seemed to divide the wreathed cylinder into two parts, a bigger and a less, the biggest at the convex side of the knee; these clefts are filled with a kind of spongy substance, very conspicuous near the knee.

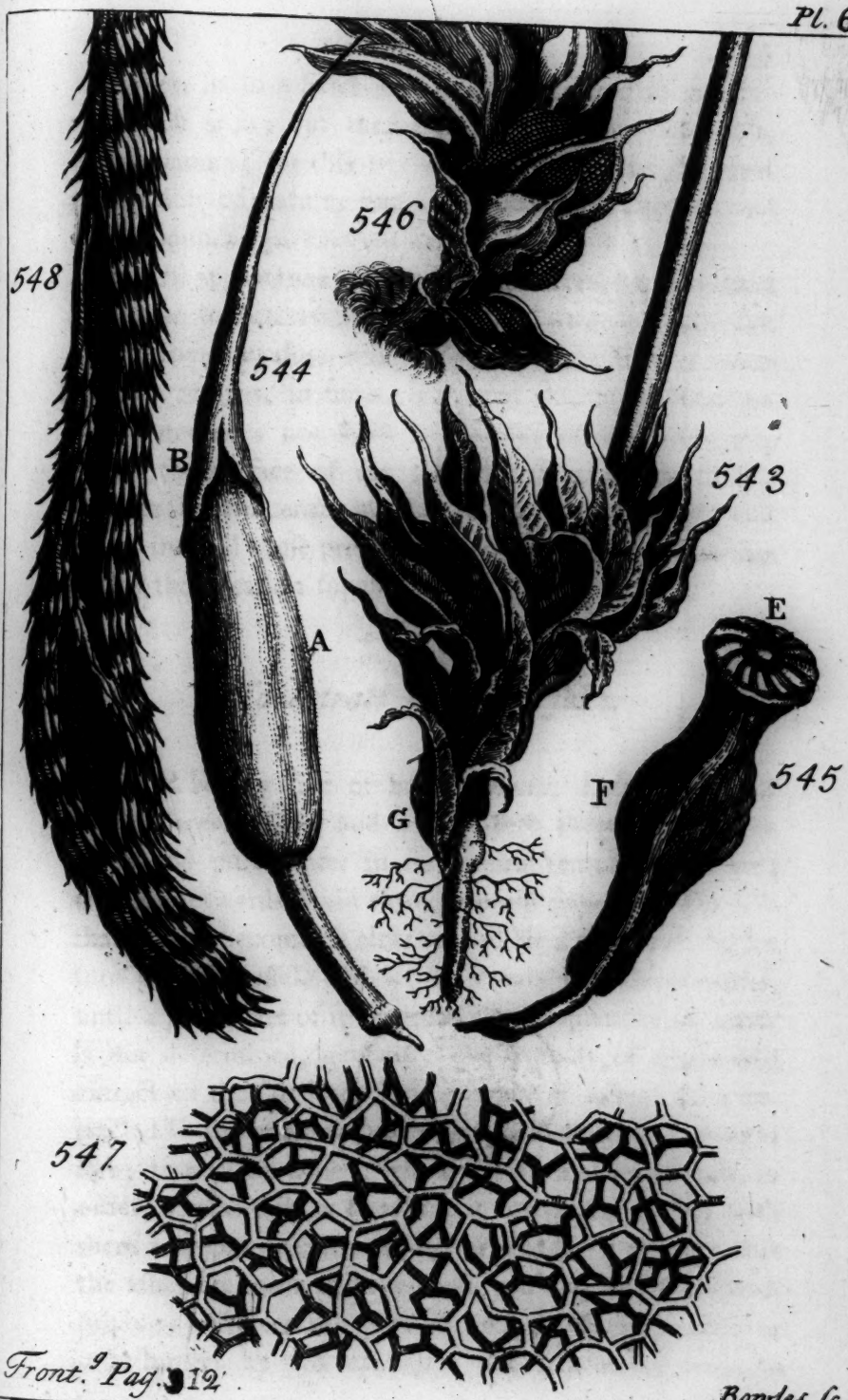
This odly constituted vegetable is sometimes used, as an hygrometer ^m, to discover the various constitutions in the moisture and dryness of the air; and this it does to admiration.

Of salts.

UNDER the denomination of salt, is to be understood most of that which gives solidity to bodies, is dissolvable in water, and affects the taste with a peculiar pungency. There are three distinct sorts which generally pass under this name, the fixed, volatile, and the essential: the fixed is what remains after calcination, and is procured by dissolving the saline parts of the ashes in hot water, and evaporating it until the salt is left dry at the bottom; for that will not rise in vapours. The volatile is what easily passes over the helm, as the salts of animals. The essential salt is that which is obtained by cristallization from the juices of plants, and is of a nature between the other two, and may most properly be termed essential, having no force used in its production.

If

^m If the reader is desirous of one of these Hygrometers, he may be furnished with them at my shop, &c.





If there be in a strict sense any such thing as a principal, salt is so; but then it must be termed fossil salt, or sal gemma; for this not only appears to be the plain production of nature, but to the most homogenous and uncompounded part nature can be divided into.

Its first appearance is in springs and rivers, being washed into them by subterraneous currents; thence by the sun it is in some measure exhaled by vapours; from whence it again returns, in snow, hail, and dews (for common rain-water does not seem to partake of it;) from this return the surface of the globe is saturated with it; whence it re-ascends in the juices of vegetables, and enters into all those productions, as food and nourishment which the creation supplies.

To extract vegetable salts.

BURN any sort of herb, flower, fruit, wood, or whatever it be, and make ashes thereof; with the ashes and pure water in its natural temper, make lee; which afterwards strain through moist paper or a filter, so that it may become as clear as possible; then put the lee into a glass vessel, and let it remain in balneo mariæ, until a great part of it evaporates; the quantity of water is not determined, generally five pounds of water will extract all the salt from two pounds of ashes; salts extracted in this manner, are wont to melt when the air is soft; to prevent which, when you burn the materials, in order to reduce them to ashes, it is requisite to use with them a proper quantity of sulphur; and if it happens that the ashes are made to your hand, you may mix them with sulphur, and keep the same at the fire, till such time as it be burnt; by this means the salt will never come to
run,

run, but become more white and crystalline. There is no general rules for the quantity of sulphur to be put into the materials you thus burn, but at a guess, to one hundred pounds of material, four or five ounces of sulphur is usually sufficient. All salts have a peculiar and determined figure, which they always keep, although they are often resolved into water, and afterwards congealed; yet notwithstanding some sorts of salts are observed to have two, three, and four sorts of figures. Two sorts have been seen in lettuce, in the scorzoneras, in the muskmelon, the scopa, in the roots of esula, in the black hellebore, in endive, eye-bright, wormwood, forrel, and in shoots of vines; three sorts in black pepper, and in incarnate roses; four sorts in white hellebore. Besides the above-mentioned diversity of figures which are found in salts, it is observable, that amongst all salts, of what figure soever, there are found some cubical, which though they be never so often dissolved and congealed, appear still of a cubical figure, or inclining to it. To make the bodies of the salts when they congeal, remain distinct from each other, that their figure may be observed, and not be entangled and heaped together, it is necessary, that very great diligence be used in evaporating the lee; for if that be wholly evaporated, or too great a part thereof, the salts make a confused crust at the bottom of the vessel; if the lees are left too weak, the salts require a very long time to congeal, and therefore it is requisite to use such diligence as is not to be gained without long practice.

Crystals of salts are such a combination of saline particles, as resemble the form of a crystal, variously modified, according to the nature and texture of salts.

The method herein used is this, dissolve the saline body in water, after which filter the solution, which being evaporated

evaporated until a little film appears upon it, runs into crystal. Dissolution and filtration are made use of, that the salts may be purged from all dross; otherwise if any foreign matter should get in, not only the transparency of the crystals would be impaired, but their figure also would be mangled and broken.

Of the figures of salts.

IT is generally agreed, that all bodies have their salts, which produce many surprising changes, by their different configurations and impressions, both in solids and fluids, in things animate and inanimate. As to the figures of them, they are obvious to every beholder; their beauty and variety are so admirable, that scarce any thing in nature can entertain the eye more agreeably than these do, when it is assisted with a good microscope.

In common salt, we plainly discover quadrilateral pyramids with square bases. In sugar, the same pyramids with oblong and rectangular bases. In allum, they rise with six sides, supported with an hexagonal base. The crystals of vitriols, resemble icicles, united one to another with great variety, among which lie some polygons. Sal-armoniac very elegantly imitates the branches of a tree; and hart's-horn looks like a quiver of arrows; Glauber's sal mirabilis, which is made of common salt and vitriol, exhibits the figure of both salts. Nitre appears in certain prismatic columns, not much unlike bundles of sticks; among which there are interspersed some of a rhomboidal, and pentagonal figure, which seem to come very near those of common salt. Hence Lemery very justly remarked, that nitre could not be purified by any art or contrivance whatsoever, but something of a sal gem, or fossil

fossil salt, would stick to it; but salt of tin out-does all for beauty, in which are lines like little needles, that spread themselves every where from a point, as from a center, so as to represent a star, much like what we see in the regulus of Mars.

Salts have this peculiar property, that let them be ever so divided and reduced into minute particles, yet when they are formed into crystals, they each of them re-assume their proper shape; so that they may be as easily divested and deprived of their saltiness, as of their figure. Whence by knowing the figure of the crystals, we may understand what the texture of the particles ought to be, which can form these crystals. And by knowing the texture of the particles, we may determine the figures of the crystals. For since the figures of the most simple parts remain always the same, it is evident the figures which they run into, when compounded and united, must be uniform and constant.

Essential salts are made by expressing the juice of any plant, and setting it in a cellar to shoot; which some do in small quantities.

Fixed salts are made as follows:

Take any plant, and burn it on a clean hearth, and rake the ashes as long as any fire appears among them; put those ashes into an unglazed pan, which set in a calcining furnace, make fire about it till the pan is red-hot; where keep it, continually stirring the ashes without any blackness. Then put them into a clean pan, and pour hot water upon them; when that water is sufficiently impregnated with salt, filter it, and evaporate to a dryness, until the ashes are left insipid.

The salts of metals or minerals are to be come at by quenching them, when red hot, in water, then filtering, evaporating, and crystallizing.

If

On striking Fire with a Flint and Steel. 317

If allum be burnt, dissolved in water, and strained, its crystals will consist of two sexangular planes, whose sides are bounded by six other, three of which are quadrilateral, having between them three of a sexangular figure; as at fig. 548.

Green vitriol affords crystals, which are made up of ten unequal sided planes, the middle-most are pentagons, and each of its sharp ends triangular planes; as at fig. 549.

The crystals of our inland salt-springs are of a cubical figure, as at fig. 550.

Salt-petre shoots into long crystals, whose sides are six parallelograms; as at fig. 551.

It has been already mentioned, that vinegar owes its pungency to the salts which float therein; their shape is seen at fig. 552. Expose a drop or two of vinegar to the open air for an hour or two upon the object-carrying glass, that its watery parts may evaporate; then apply it to the microscope.

The salts of sugar candied, are represented at fig. 553. The salts of nitre are seen at fig. 554. The salts of camphire, at fig. 555. Sal gem is represented at fig. 556. and sal armoniack at fig. 557.

It is best to examine all salts in the smallest masses, for in them their shape will be best discovered.

On striking fire with a flint and steel, &c.

ON striking fire with a flint against a steel, little particles of steel are struck off, and melted into globules by the collision; which will be evident on spreading a sheet of white paper, and observing the place where several of these little sparks seem to vanish. Mr.

Hook

318 *On striking Fire with a Flint and Steel.*

Hook examined several of them with a microscope, and found that a black particle, no bigger than a pin's point, appeared like a ball of polished steel, as at fig. 558. and strongly reflected the image of the window, and of a stick which he moved up and down between the light and it. Others were, as to their bulk, pretty round, but their surface not so smooth; some were cracked, as fig. 559. others broke in two, and hollow, as fig. 561. several others were found of other shapes; but that represented at fig. 560. was observed to be a big spark of fire, and stuck to the flint, by the root F, at the end of which stem was fastened an hemisphere, or hollow ball. It is also remarkable, that some of these sparks are slivers, or chips of iron vitrified, others are only the slivers melted into balls, without vitrification ^a, and the third kind are only small slivers of the iron, made red-hot with the violence of the stroke given on the steel by the flint.

Many sorts of sand, some gathered on the sea-shore, or on the sides of rivers, and some found on the land, differ in the size, form, and colour of their grains, some being transparent, others opaque, some have rough, and others quite smooth surfaces. It would be endless to describe all the figures to be met with in these kind of minute bodies, they being spherical, oval, pyramidal, conical, prismatical, &c. Mr. Hook trying several magnifying glasses, by viewing a parcel of white sand, casually hit upon one of the grains, which was exactly shaped and wreathed like a shell, which he separated from the rest of the granules, and found it to appear to the naked eye no bigger than a pin's point, but when viewed in the microscope, it appeared as in fig. 562. resembling the shell of a small water snail ^o; it had twelve wreathings, growing all proportionably one less than the other, towards

^a Hook's Mic. p. 44.

^o Ibid. p. 80.

wards the middle or center of the shell, where there was a very small round white spot. In this minute shell we have a very good instance of the curiosity of nature, in another kind of animals, removed by their smallness beyond the reach of the naked eye; and as there are several sorts of insects and vegetables, so small as to have had no names; so likewise by this, we find there are also exceeding small, or rather minute shell-fish. Nature, by the assistance of the microscope, having shewn to us her curiosities, in every tribe of animals, vegetables, and minerals.

Of small diamonds or sparks in flint.

A Flint stone being broke in pieces, the inside cavity of it appeared to be crufted all over with a pretty candid substance, reflecting the light from some of its parts very vividly; but on examining it with the microscope, the whole surface of that cavity could be perceived to be beset with a multitude of little crystalline or adamantine bodies, curiously shaped, as at B, fig. 563^d and afforded a very agreeable object.

An atom, or globule of quicksilver, when placed before the microscope, seems like a convex mirror, in which may be seen all the circumambient bodies; as the windows, trees, and furniture, &c.

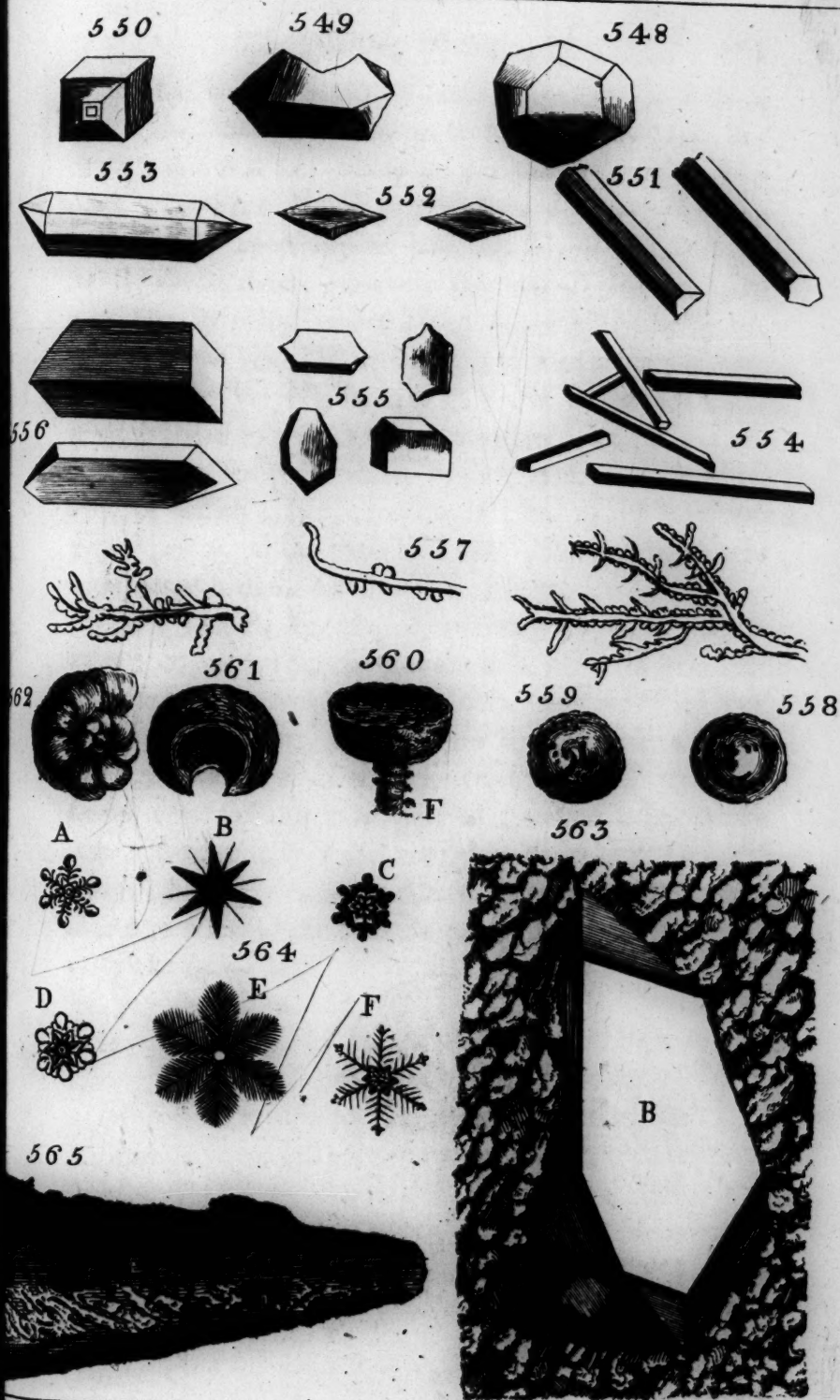
Of mercurial powders, &c.

IN those chymical preparations of mercury, which is called turbith mineral, mercurius vitæ, dulcis, sublimatus, precipitate, and mercury cosmetical, calomel, and all other mercurial powders, are found, when examined
by

by the microscope, to be full of minute globules of crude and unaltered mercury; which shews, that those chymical preparations are not so purely exalted and prepared as they are presumed to be, nor the mercury any way transmuted, but by an atomical division rendered insensible.

The nature of snow.

MANY of the parts of snow are for the most part of a regular figure, and as it were so many rowels or stars with six points, and are as perfect and transparent ice ^P as any we see on a pool of water; at each of these six points are set other collateral points, and these always at the same angles with the principal points themselves; that amongst these, many others alike regular, but far smaller, may be discovered; there are also some others, which seem to have lost their regularity, by various winds, being first gently thawed, and then frozen again into irregular masses; from all which, snow seems to be an infinite number of icicles, regularly figured, not only in some few parts thereof, but originally in the whole body of it; not so much as one particle of so many millions being originally indeterminate or irregular; that is, a cloud of vapours being gathered into drops, do forthwith descend; in which descent, meeting with a freezing wind, or at least passing through a colder region of the air, each drop is immediately frozen into an icicle, shooting itself into points or icicles on all sides from the center; but still continuing their descent, and meeting with warmer air, some are thawed and blunted, others broken, but the greatest number cling together in several parcels, and form



form which we call flake of snow; hence we understand that snow, though it seems to be soft, is really hard, because it is a real ice, whose inseparable property is to be hard, its flakiness being only apparent. The first touch of the flake upon any of its sharp edges or points in the hand, answers them, otherwise they would pierce the hand, as many lancets; and hence also why snow, though soft to the touch, and so dense and hard a body is not so much as to be very light, which is the extreme thinness of each flake in respect of its breadth; hence it also appears why snow is white, because it consists of parts, each of which singly is transparent, but mixed together, as the parts of flesh, glass, ice, and other transparent bodies, whether soft or hard.

THESE, &c. represent a few of an infinite number of various figures that are to be observed in snow, in which it was observable, that if they were of any regular figure, they were always branched out with six equal branches, of equal length and shape. As there were some for the most part of the same make in one flake, to wit, they in differently figured flakes, very different from each other, it was manifestly evident, that what was one of the branches were one the rest were exactly the same.

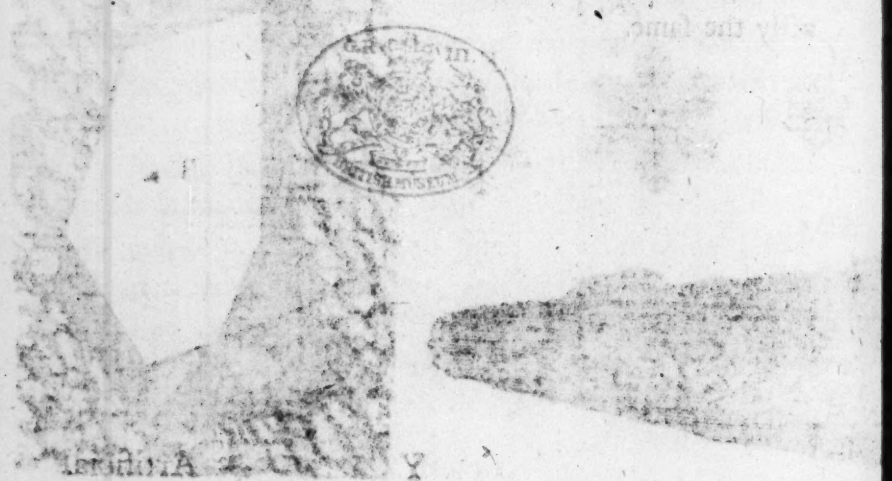


Fig. 1. A single flake of snow.

form what we call flakes of snow; hence we understand why snow, though it seems to be soft, is really hard, because it is a real ice, whose inseparable property is to be hard, its softness being only apparent. The first touch of the finger upon any of its sharp edges or points instantly thaws them, otherwise they would pierce the fingers like so many lancets; and hence also why snow, though a real ice, and so dense and hard a body is notwithstanding very light, which is the extream thinness of each icicle in respect of its breadth: hence it also appears, why snow is white, because it consists of parts, each of which singly is transparent, but mixed together, appear white, as the parts of froth, glass, ice, and other transparent bodies, whether soft or hard.

A B C D E F, fig. 564. represents a few of an infinite variety of curious figures that are to be observed in snow; in which it was observable, that if they were of any regular figures, they were always branched out with six principal branches, of equal length and shape. As these stems were for the most part of the same make in one flake, so were they in differently figured flakes, very different; but this was constantly observed, that whatever figure one of the branches were of, the rest were exactly the same.

Artificial things.

THE point of an exceeding small needle appeared, when greatly magnified, like fig. 565. neither round nor flat, but very irregular, and though to the naked eye it was very smooth and sharp, yet upon this examination, it appeared to be full of holes^a and scratches; so inaccurate is human art in all its productions, even in these which seem to be the most neat, that if examined with an organ more accurate than that by which they were made, the more we see of their shape, the less appearance will there be of their beauty; whereas in the works of nature, the deepest discoveries shew us the greatest excellencies; for in the sting of a gnat, or a bee, the proboscis of a butterfly, or flea, they appear, when examined by the microscope, to be formed with the most surprising beauty, exquisite workmanship, and an exact regularity of, and likeness in parts is preserved in each particular of every species; an evident argument, that he who was, and is the author of all these things, is no other than Omnipotent; being able to include as great a variety of parts and contrivances in the most minute point, as in the largest body.

Fig. 566. represents a very small dot, tittle, or point, that is generally the mark of a full stop or period. Amongst multitudes that were observed by the microscope, few could be found so round and even as this here delineated^r, but when greatly magnified, it appeared to be rough, jagged, and uneven all about its edges, and very far from being truly round, as at fig. 567. the most curious and smoothly

^a Hook's Mic. p. 2. ^r Hook's Mic. p. 2.

smoothly engraved strokes and points, when examined by the microscope, look but like so many furrows and holes; and their printed impressions, but like smutty daubings on a mat, or uneven floor, made with a blunt extinguished brand. Several pieces of small writing, reckoned very curious of their kind, one of which in the breadth of a silver two-pence, comprized the Lord's prayer, the apostles creed, the ten commandments, and about six verses besides out of the bible, being examined by the microscope, shewed what the writer had asserted was true, but withal discovered it to be composed of as shapeless, barbarous, and uncouth letters, as if written in Arabian and Chinese characters.

A part of the edge of a very keen razor was so placed between the microscope, and the light, that there appeared a reflection from the very edges, and was perceived to be sharper in some places than in others, indented at others, broader and thicker at others, and unequal and rugged; that part of the edge which is polished by the hone, appeared to be prodigiously full of scratches, crossing each other every way; besides it had several deep furrows. That part of the razor which was polished upon the wheel, looked almost as rough as a plowed field.

Mr. Leeuwenhoek caused himself to be shaved with the sharpest razor he could pick out of five by the help of a magnifying glass. At first it was very soft and easy, but at last it grew so painful he could not endure it, and upon viewing it with his microscope, he found in it many more notches than at first. In another he found little holes in six several places near the edge. He washed the back of his hand with plain water, and then with this same razor scraped off the little hairs, and on observing

the razor again, found that those little holes were turned into notches, and that several pieces of the razor were broken out. From whence it appears, that if the razor be too soft, it yields to the hairs, if too hard, the hair causes several notches in it. In short when we observe through a microscope the several notches there are in the finest razor, it is surprising how any of them can cut so well.

Fig. 568. represents a piece of exceeding fine lawn, as it appeared through the microscope, which from the great distances between its threads, appears like a lattice, and the threads themselves seem coarser than rope-yarn.

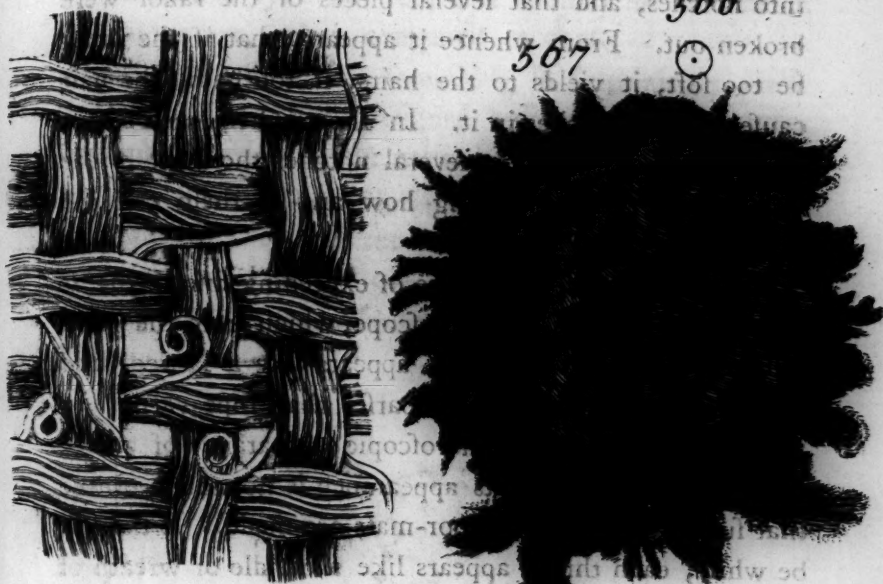
Fig. 569. exhibits a microscopic appearance of a very fine piece of ribband, its appearance is not much unlike that substance of which door-mats are made. If the silk be white, each thread appears like a bundle or wreath of transparent cylinders; if coloured, they appear curiously tinged, each of which affording in some part or other a vivid reflection, in so much, that the reflection of red appeared as if coming from so many garnets or rubies.

Hence it is evident, that there are but few artificial things worth observing with a microscope, for which reason I shall conclude here; the productions of art being such rude misshapen things, that when viewed with a microscope, we can observe very little in them but their deformity. The most curious carvings, appear no better than those rude Russian images mentioned by Purchas; where three notches at the end of a stick stood for a face: and the most smooth and polished surfaces that we can possibly meet with, appear rough and uneven. Therefore why should we endeavour to find beauties in things which were designed for no higher use than to be viewed
by

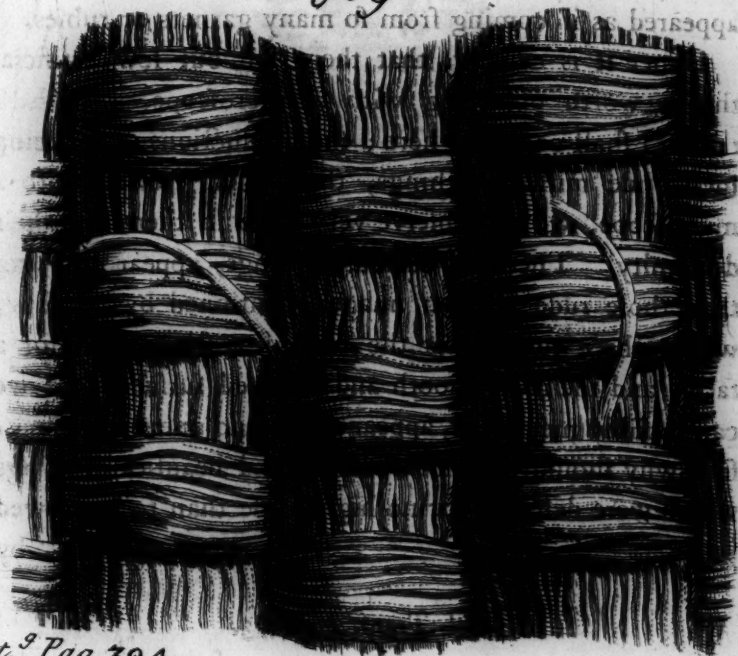
568

566

567



569



...but only that we may see the desire
...compared to those of persons in
...something to improve (moral)
...and then desired better to remove
...in our natural state, but the power
...the more we are enabled to do
...own souls as well as
...and humane intentions of the



by our naked eye? but only that we may see the defects of human art, when compared to those of nature, in whose forms there are something so surprizingly small and curious, and their designed business so far removed beyond the reach of our natural sight, that the more we magnify those minute objects, the more excellencies and mysteries appear; and the more we are enabled to discover the weakness of our own senses, as well as the Omnipotency and infinite Perfections of the Great Creator.

F I N I S.



CATALOGUE



Mathematical, Philosophical, and Optical

INSTRUMENTS

Made under the Inspection and Direction of
 GEORGE ADAMS, Mathematical In-
 strument Maker to his Majesty George
 the Third.

At the Sign of Tycho Brahe's Head, No. 60. in
 Fleet-Street, London.

Where Gentlemen, Ladies, and Merchants, &c. may be
 supplied with Instruments which are invented, and im-
 proved by him, as well as with those contrived by the
 ablest Mathematicians in Europe.

THE study of the mathematicks being
 now become a necessary part of every
 Gentleman's education, we need not won-
 der at the great progress which this science has
 in late years, made in most parts of Europe;
 since it contains such an inexhaustible fund of
 useful knowledge, as is sufficient to gratify every
 taste, and employ every talent. The noblest ge-
 nius may, in the pursuit of it, exert his utmost
 faculties, and the meanest will not fail of finding
 something that is within his reach. The theory
 affords an ample field to the speculative part of
 mankind, and the practice is productive of several
 advantages to men of action and business.

Mathematical

A
C A T A L O G U E
O F

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affords an ample field to the speculative part of
mankind, and the practice is productive of several
advantages to men of action and business.

Mathematical

Mathematical instruments are the means by which those noble sciences, geometry, philosophy, astronomy and opticks, are rendered useful in all the common and necessary occurrences of human life. By their assistance an abstracted and unprofitable speculation, is made beneficial in a thousand instances: in a word, they not only enable us to connect theory with practice, but also instruct us how to turn bare contemplation, into the most substantial use, by making one of the most serviceable branches of learning, the natural way of rendering this knowledge general and diffusive.

The knowledge of these leads to that of practical mathematicks, and experimental philosophy; so that the uses of mathematical and philosophical instruments, make perhaps one of the most serviceable branches of learning in the whole world; and the natural way, therefore, of rendering this knowledge general and diffusive, is by making that of its instruments so.

As practical mathematicks, and experimental philosophy, teach us the powers of nature, the properties of natural bodies, and their mutual actions on one another; this knowledge cannot be attained without instruments, and the conclusions and proofs we expect from it, depend very much upon their exactness. In order therefore to give a sufficient satisfaction to those who honour me with their custom, it is my particular and greatest aim to produce such instruments as may facilitate the progress of mathematical and philosophical learning.

In all my performances I endeavour not to augment the instruments with superfluous ornaments, that they may be of frequent use to those of middling fortunes, and also that their neatness may render

render them not unworthy of a place in the cabinets of the curious.

That their exactness may be particularly attended to, I always inspect and direct the several pieces myself, see them all combined in my own house, and finish the most curious parts thereof with my own hands. That the construction may be as simple and substantial as the use of each instrument will admit, it is my constant study to contrive them in such a manner that they may be managed with the greatest ease. I also have respect to their being made applicable to several operations, especially when the extent of their uses does not prejudice their simplicity, to the end that instruments may not be multiplied without necessity.

In the following catalogue I have ranged the instruments in classes under the heads of their several branches, and have numbered each particular instrument, so that if a gentleman is desirous of any one or more of them, and is at any distance from London, he need only send me the numbers adjoining to those he intends to purchase, and he shall be served with fidelity, and at the lowest prices.

Instruments for Geometry, Drawing, &c.

Variety of pocket cases of drawing instruments, in silver, brass, ivory, or wood, from 10s. 6d. to 5l. 5s. These contain more or less of the following articles, which limit their price.

- 1 Plain compasses for measuring lines, &c.
- 2 Drawing compasses, with moveable points, viz. an ink point for sweeping circles, or arches of any determinate thickness, and a black lead point.

3. Drawing

3 Drawing pens, either with or without a protracting pin.

4 Sectors, for finding proportions between quantities of the same kind, as between lines and lines, surfaces and surfaces, &c. either of box, ivory, brass, silver, &c.

5 Plain scales, or,

6 Square protractors, or,

7 Parallel Rules, are

8 Semicircle protractors, of brass.

} either of box, ivory,
brass, silver, &c.

In the best cases, the compasses are always made with steel joints, and the knibs of all the pens are made to open with a joint, in order to clean them, in which are also sometimes put,

9 Hair compasses, so contrived on the inside of one of the legs, that an extent may be taken to an hair's breadth.

10 Circular (or bow) compasses, with which a circle as small as a pin's head may be described.

In a magazine case of drawing instruments, is generally contain'd all the above instruments, together with the following particulars,

11 Drawing compasses, with moveable legs longer than those of No. 2.

12 Strong compasses, with calliper and cutting points.

13 Beam compasses, for drawing larger circles, and taking larger extents.

14 Proportionable compasses, for the ready diminishing plans or drawings, in any assigned proportion.

15 12 Inch Brass Sectors, of a new construction.

16 Triangular compasses, for transferring three points

points at once, from a map or any drawing to another copy.

- 17 A pointrel and feeder, having at its upper end an oval plate for clearing the drawing pen of any dirt or grit that may happen between the knibs, and in the middle thereof is a protracting pin.
- 18 Elliptical compasses, for describing ellipsis of various excentricities.
- 19 Bows, for drawing curved lines.
- 20 Port craiyons.
- 21 Large plain scales.
- 22 Plotting scales.
- 23 Protractors.
- 24 Plain and parallel rules, of several sizes.
- 25 Ivory pallates for Indian ink and colours.
- 26 Gunners callipers.
- 27 The regular solids, or platonick bodies cut in wood.
- 28 Cylinder bisected.
- 29 Cones with all their proper sections.
- 30 Flat plates, for describing the conic sections upon paper, designed for those who are studying that branch of science.

} Sometimes these are all
made in one instrument.

In these magazine cases, gentlemen may have what number of instruments they think proper.

Rules of all sorts, for measuring of timber, stone, painting, brick-work, &c. at the usual prices.

Surveying

Surveying Instruments, &c.

31 **P**LAIN tables, with an index and sights, whereby the draught or plan is taken on the spot, without any future protraction, having a compass fitted to one of its sides, and the whole fixed upon a ball socket, with a three legg'd staff, upon which it may be turn'd round, or fasten'd with a screw, as occasion requires.

32 Beighton's plain tables, with an index, whereby the line of sights is always over the center of the table, the station lines drawn parallel to those measured on the land; and the table set horizontal by a spirit level. In this table the papers being square, are readily laid together and compose the whole survey in one view.

Theodolites for measuring angles, distances, altitudes, &c. Those instruments are made various ways, some being more simple and portable, others more accurate and expeditious.

33 The plain theodolite, which consists of four plain sights, two fastened to the limb, and two on the ends of the index, with a compass on the index plate, divided into degrees, and the limb subdivided into minutes by a nonius division, the whole fitted on a ball and socket, and that placed upon a three-legg'd staff.

34 Theodolites, with all the above particulars, and the addition of a telescope.

35 Theodolites of the latest improvement, being the most accurate instrument yet invented for surveying land, which may be set truly horizontal,

zontal, by parallel plates and screws. On the index, and over the compass-box is fixed a double sextant, which moves exactly in a vertical circle, with a spirit level, and over that a telescope, so contrived, that when the bubble rests in the middle of the spirit tube, the intersection of the hairs in the telescope will cut an exact level. The double sextant is divided in such a manner as to shew on one side thereof the degrees and minutes of any altitude or depression within the extent of its divisions. On the other side are divisions for taking the height of timber standing in feet; and on the limb, there are also divisions for measuring its breadth. It must be also observed here, that both horizontal and vertical angles are observed at the same time, which is extremely useful in laying down plots, when the hypothenuzal are to be reduced to horizontal lines; when the telescope is directed to any object, the whole instrument is fixed in so firm a manner, that on directing the telescope to the next, the limb remains entirely stedfast, which in other instruments of this sort, is very difficult to be effected.

36 Circumferentors, the principal surveying instrument used in the West Indies. It is very simple, yet expeditious in the practice, and consists only of a brass circle, with a compass divided into 360 degrees, on the center of which is suspended a magnetic needle, and an index, on whose extremities are two sights; the whole is mounted on a staff, and sometimes for conveniency, on a ball and socket.

37 Gunters, or four pole chains:

38 Air levels which shew the line of level, by means of a bubble of air and spirits of wine hermetically

- hermetically inclosed within a glass tube for the pocket.
- 39 Air levels, with telescope sights, mounted on a three-legg'd staff; they have a particular contrivance, by which they may be adjusted (if put out of order) to a true level at any one station.
- 40 Gunners levels, generally called perpendiculars.
- 41 Levelling staves
- 42 Plotting scales.
- 43 Feather edged scales.
- 44 Pantographers, for reducing, or enlarging, or copying plans of surveys, pictures of any kind, and reducing shadows of the human side face, and this without any previous habit of drawing.
- 45 Pedometers to measure the way in walking.
- 46 Perambulators, way-wisers, or measuring-wheels, ditto for coaches.
- 47 Major General Williamson's new instrument for elevating pieces of ordnance.

Optical Instruments.

- | | | | | |
|----|--|----|----|---|
| 48 | R eflecting telescopes, 12 inches. | 5 | 5 | 0 |
| 49 | Ditto 18 inches. | 8 | 8 | 0 |
| 50 | Ditto 2 feet. | 12 | 12 | 0 |
| 51 | Ditto on a rack stand. | 21 | 0 | 0 |
| 52 | Achromatic prospects for the pocket. | 1 | 16 | 0 |
| 53 | Achromatic telescopes, either in nurse skin for the pocket, or mahogany tubes, 2 feet. | 2 | 2 | 0 |
| 54 | Ditto 3 feet. | 3 | 3 | 0 |
| 55 | Ditto 4 feet. | 4 | 4 | 0 |
- And

Mathematical Instruments.

9

And so in proportion for any other length.

All other sorts of refracting telescopes at the usual prices.

56	Wilson's pocket microscope.	2	2	0
57	Ditto. ——— ———	2	12	6
58	Ellis's aquatic microscope.	2	2	0
59	Ellis's and Wilson's microscope in one case. ——— ———	4	15	6
60	A single and double aquatic microscope. ——— ———	7	7	0
61	The double constructed microscope.	6	6	0
62	Ditto with a triangular foot in a mahogany case. ——— ———	8	8	0
63	Culpepper's double microscope.	3	3	0
64	A solar microscope. ——— ———	4	14	6
65	A ditto. ——— ———	5	15	6
66	The new variable microscope.			
67	A solar microscope, to be applied to a new invented camera obscura, that may be used either in the sun-shine, or with a lamp contrived for that purpose in winter evenings.			
68	A pocket camera obscura.	0	10	6
69	A ditto. ——— ———	1	1	0
70	A ditto larger. ——— ———	1	5	0
71	A pyramidical camera obscura in wainscot. ——— ———	3	3	0
72	Ditto in mahogany. ——— ———	4	4	6
73	An instrument for taking perspective views. ——— ———	6	6	0
74	Concave and convex mirrors, from ——— ———	7s. 6d.	to 26	0 10
75	Prisms, from ——— ———	7s. 6d.	to 2	2 0
76	Zografcopes for viewing prints, from ——— ———	18s.	to 3	3 0
77	Opera glasses. ——— ———	0	8	10
78	Ditto. ——— ———	0	15	10
79	Ditto			

Pneumatical Instruments.

96	A IR pumps exclusive of any apparatus.	—	21	2	0
97	Single barrelled.	—	4	4	0
98	Small double barrelled.	—	6	6	0
99	Ditto larger.	—	10	10	0
100	A large table air pump.	—	21	0	0
101	A large standing air pump.	—			
The apparatus to either of these according to the desire of the purchaser.					
102	Portable barometers.	—	2	2	0
103	Ditto with spirit thermometers.	—	2	12	6
			204	Ditto	

Mathematical Instruments.

11

104	Ditto with mercurial thermometers.	4	4	0
105	Ditto with ditto and hygrometers.	4	14	6
106	Ditto with ditto and ditto, with glass doors. ———	6	6	0
107	Other barometers with open cisterns of several curious constructions, of a new contrivance, with diagonal barometers, either with single, double or triple tubes. Wheel barometers, &c. all at reasonable prices.			
108	Farenheidt's thermometers.	1	11	6
109	Ditto for the pocket.	1	1	0
110	Botanic thermometers.	0	18	0

Astronomical and Geographical Instruments.

111	N EW Globes accurately delineated, neatly engraved, and adapted to an apparatus easy in application, and extensive in their use, 18 inches diameter in stained frames. ———	9	9	0
112	Ditto in mahogany frames.	11	11	0
113	Ditto in carved frames.	24	0	0
114	New globes, 12 inches diameter in stained frames. ———	5	5	0
115	Ditto in mahogany frames.	6	16	6
116	New globes, 6 inches diameter in stained frames.			
117	Ditto in mahogany frames.			
118	Globes 3 inches diameter in frames.	1	11	6
119	Ditto in black cases for the pocket.	0	10	6
120	Globes mounted with wheel-work, at various prices.			
121	Armillary spheres, 12 inches diameter. ———	21	0	0

Z

122 An

- 122 An armillary dialling sphere, so contrived as to explain the reason and nature, as well as to solve the most useful problems in spherics, and illustrate the theory of dialling, and is itself an universal sun-dial.
- 123 A sphere shewing the real and apparent motion of the heavens, and solving the problems depending thereon.
- 124 A planetarium, by which the annual motion of the planets, their situations and positions with respect to the earth and sun, as well as to each other, with their direct stationary and retrograde appearances are clearly illustrated. 18 18 0
- 125 A tellurian, which explains the diurnal and annual motions of the earth and moon; shews the inclination and retrograde motion of the moon's orbit, and thereby the causes of the eclipses of the sun and moon, the causes of day and night, the vicissitudes of the seasons, the phases of the moon, the difference between a periodical and synodical month, the rising, southing, meridian altitude, declination, amplitude, and setting of the sun and moon, &c. 26 15 0
- 126 Orreries, which shew all the above phenomena, with the motion of the inferior planets only, or with the motions of all the superior planets and their satellites, with many improvements, are made by me at various prices, according to the intention

Mathematical Instruments.

13.

intention or desire of the persons who propose to be purchasers, from

130 guineas, to 1500 0 0

Smaller instruments of this kind, designed to shew only a few of the particular phenomena, are made at various prices.

127	Astronomical quadrants, 3 feet radius.	130	0	0
128	Ditto, 2 feet radius,	70	0	0
129	Ditto, 18 inches radius,	50	0	0
130	Ditto, 12 inches radius.	31	10	0

And all other astronomical instruments, as sectors for observing angular distances and differences in right ascension, equal altitude instruments, and transit instruments, &c. of various prices according to their size, &c.

Navigation Instruments.

131	H ADLEY's quadrant.	2	0	0
132	Ditto.	2	12	6
133	Ditto.	3	3	0
134	Ditto.	4	4	0
135	Hadley's sextant.	8	8	0
136	Dr. Knight's steering compass.	2	12	6
137	———— azimuth compass.	5	15	6

These with all sorts of scales, rules, and all the instruments used in experiments of natural philosophy, for mechanicks, pneumatics, hydrostatics, &c. are made, when ordered, at moderate prices.

To

To enumerate all the various articles that are used in making experiments, or for other purposes, would alone fill a volume. I have therefore selected the principal instruments in use, to most of which I have affixed prices and numbers, for the ease of those gentlemen and ladies at any distance from London, who may have occasion to write for any of the above instruments,

To their humble servant,

GEORGE ADAMS,

At No. 60. in Fleet-Street, LONDON.



A. Catalogue, &c.

To illustrate all the various instruments
used in making experiments, or for other pur-
poses, would alone fill a volume. I have therefore
selected the principal instruments in use, and
of which I have affixed prices, and annexed
the case of those gentlemen and ladies who
reside from London, who may have occasion
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